



Intel® Pentium® 4 Processor

Specification Update

July 2003

Notice: The Intel® Pentium® processor may contain design defects or errors known as errata which may cause the product to deviate from published specifications. Current characterized errata are documented in this Specification Update.

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Revision History

Revision Number	Description	Date
-001	Initial Release	November 2000
-002	Added errata numbers N41-N44.	December 2000
-003	Updated Intel® Pentium® 4 Processor Identification Information. Updated erratum N40. Added errata N45 through N46.	January 2001
-004	Added errata N47.	February 2001
-005	Updated the processor identification information table. Removed <i>Possible system hang due to cacheable line-split loads with page-tables in uncacheable (UC) space</i> and <i>Uncacheable memory type prevents physical address code breakpoint match</i> erratum. Renumbered remaining errata. Modified the workaround for N45. Added errata N46 and N47. Added processor marking information.	March 2001
-006	Updated plans column for errata N6, N7, N10, N11, N14, N18, N19, N21, N23 – N28, N30 – N35, and N41	March 2001
-007	Added information for the Intel® Pentium® 4 processor in the 478-pin package. Added erratum N48.	April 2001
-008	Updated the Intel® Pentium® 4 Processor Identification Information table. Added erratum N49.	May 2001
-009	Updated Specification Update product key to include the Intel® Xeon™ processor. Updated erratum N45, added erratum N50 and Specification Change N1.	June 2001
-010	Added errata N51 and Specification Clarification N1. Updated Intel® Pentium® 4 Processor Identification Information table.	July 2001
-011	Added errata N52 and N53 and Specification Clarification N2.	August 2001
-012	Release for launch of new frequencies and the 478-pin package. Updated Intel® Pentium® 4 Processor Identification Information table.	August 2001
-013	Added errata N54 – N56.	September 2001
-014	Added erratum N57. Added Specification Clarification N3. Updated Intel® Pentium® 4 Processor Identification Information table.	October 2001
-015	Added Documentation Changes N1 and N2.	November 2001
-016	Added erratum N58 and Documentation Change N3.	December 2001
-017	Added Intel® Pentium® 4 Processor with 512-KB cache in 0.13 micron process information.	January 2002
-018	Added Documentation Change N4.	January 2002
-019	Added errata N60 and N61.	February 2002
-020	Added Documentation Change N5	March 2002
-021	Added errata N62 and N63. Removed Documentation Changes, Specification Clarifications, and Specification Changes that have been incorporated into documentation. Added Specification Clarifications N1 – N5.	April 2002

Revision Number	Description	Date
-022	Updated erratum N37. Added errata N64. Added Specification Change N1 to N3. Removed Documentation Changes that have been incorporated into the documentation. Added Documentation Changes N1 and N2.	May 2002
-023	Added erratum N65. Removed Documentation Changes that have been incorporated into the documentation. Added Documentation Change N1 and N2.	June 2002
-024	Added erratum N66. Removed Documentation Changes that have been incorporated into the documentation. Added Documentation Changes N3 to N12.	July 2002
-025	Removed Documentation Changes that have been incorporated into the documentation.	August 2002
-026	Added 2.80 GHz and C1 stepping information.	August 2002
-027	Updated erratum N39. Added Documentation Changes N3 to N24.	September 2002
-028	Added erratum N67. Added Documentation Changes N25 to N32.	October 2002
-029	Added Package Markings under General Information. Added Erratum N68. Added Specification Clarification N1. Added Specification Changes N3 and N4. Added Documentation Changes N33-42.	November 2002
-030	Added eight S-spec numbers under identification information table.	December 2002
-031	Added Errata N69 and N70.	January 2003
-032	Added Erratum N71.	February 2003
-033	Added full graphics range to General Information section. Minor typographical errors from text conversion corrected.	February 2003
-034	Updated Erratum N70. Added new Errata N72 and N73. Added S-spec numbers under identification information table.	March 2003
-035	Added S-spec numbers under identification information table.	April 2003
-036	Added Erratum N74. Added Specification Clarification N2.	May 2003
-037	Added Erratum N75 and Updated Errata N68 and N74.	June 2003
-038	Added 3.20 GHz S-spec number information.	June 2003
-039	Added Errata N76 and N77.	July 2003

Preface

This document is an update to the specifications contained in the documents listed in the following Affected Documents/Related Documents table. It is a compilation of device and document errata and specification clarifications and changes, and is intended for hardware system manufacturers and for software developers of applications, operating system, and tools.

Information types defined in the Nomenclature section of this document are consolidated into this update document and are no longer published in other documents. This document may also contain information that has not been previously published.

It is intended for hardware system manufacturers and software developers of applications, operating systems, or tools. It contains S-Specs, Errata, Documentation Changes, Specification Clarifications and Specification Changes.

Affected Documents

Document Title	Document Number
<i>Intel® Pentium® 4 Processor in the 423-pin Package</i> datasheet	http://developer.intel.com/design/pentium4/datashts/249198.htm
<i>Intel® Pentium® 4 Processor in the 478-pin Package</i> datasheet	http://developer.intel.com/design/pentium4/datashts/249887.htm
<i>Intel® Pentium® 4 Processor with 512-KB L2 Cache on 0.13 Micron Process</i> datasheet	http://developer.intel.com/design/pentium4/datashts/298643.htm

Related Documents

Document Title	Document Number
<i>Intel Architecture Software Developer's Manual, Volume 1: Basic Architecture</i>	http://developer.intel.com/design/pentium4/manuals/245470.htm
<i>Intel Architecture Software Developer's Manual, Volume 2: Instruction Set Reference</i>	http://developer.intel.com/design/pentium4/manuals/245471.htm
<i>Intel Architecture Software Developer's Manual, Volume 3: System Programming Guide</i>	http://developer.intel.com/design/pentium4/manuals/245472.htm



Nomenclature

S-Spec Number is a five-digit code used to identify products. Products are differentiated by their unique characteristics, e.g., core speed, L2 cache size, package type, etc. as described in the processor identification information table. Care should be taken to read all notes associated with each S-Spec number

Errata are design defects or errors. Errata may cause the Intel® Pentium® processor's behavior to deviate from published specifications. Hardware and software designed to be used with any given stepping must assume that all errata documented for that stepping are present on all devices.

Specification Changes are modifications to the current published specifications. These changes will be incorporated in the next release of the specifications.

Specification Clarifications describe a specification in greater detail or further highlight a specification's impact to a complex design situation. These clarifications will be incorporated in the next release of the specifications.

Documentation Changes include typos, errors, or omissions from the current published specifications. These changes will be incorporated in the next release of the specifications.

General Information

Figure 1. Intel® Pentium® 4 Processor in the 423-Pin Package and Boxed Pentium 4 Processor in the 423-Pin Package Markings

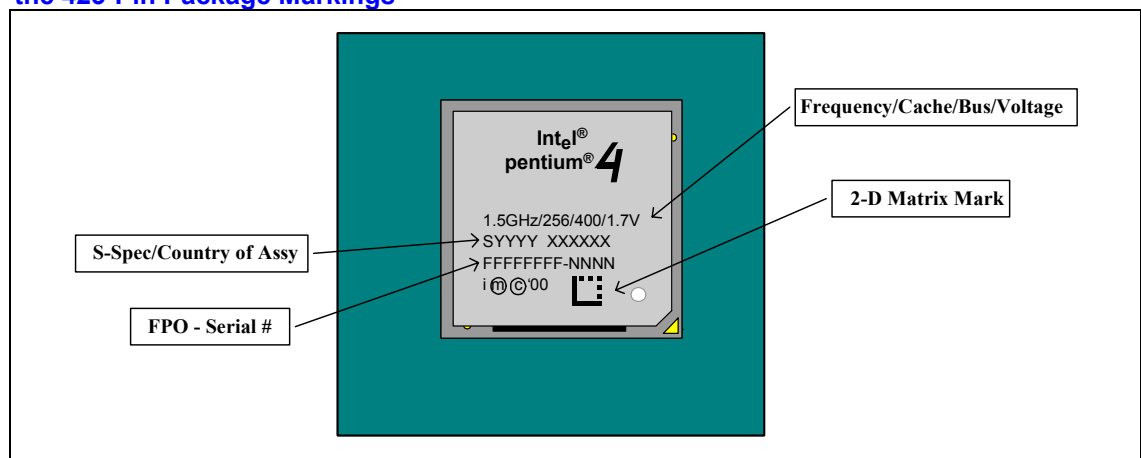


Figure 2. Intel® Pentium® 4 Processor in the 478-Pin Package and Boxed Pentium 4 Processor in the 478-Pin Package Markings

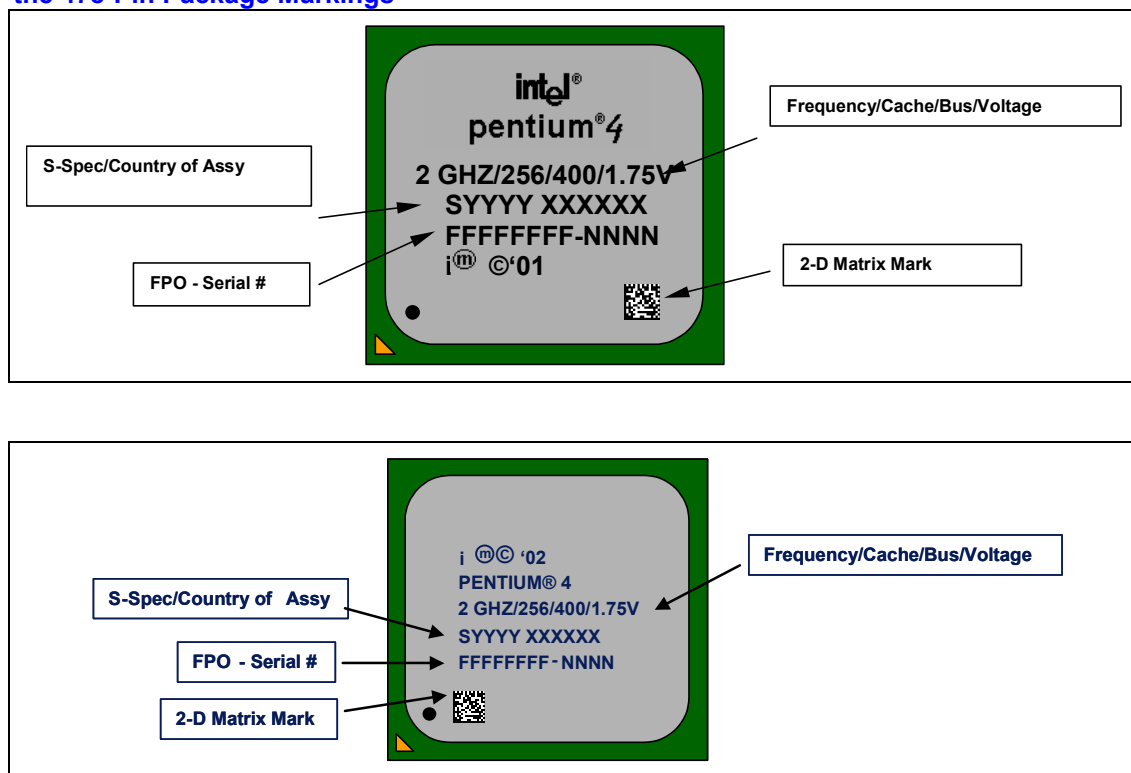


Figure 3. Intel® Pentium® 4 Processor with 512-KB L2 Cache on 0.13 Micron Process and Boxed Pentium 4 Processor with 512-KB L2 Cache on 0.13 Micron Process Processor Markings

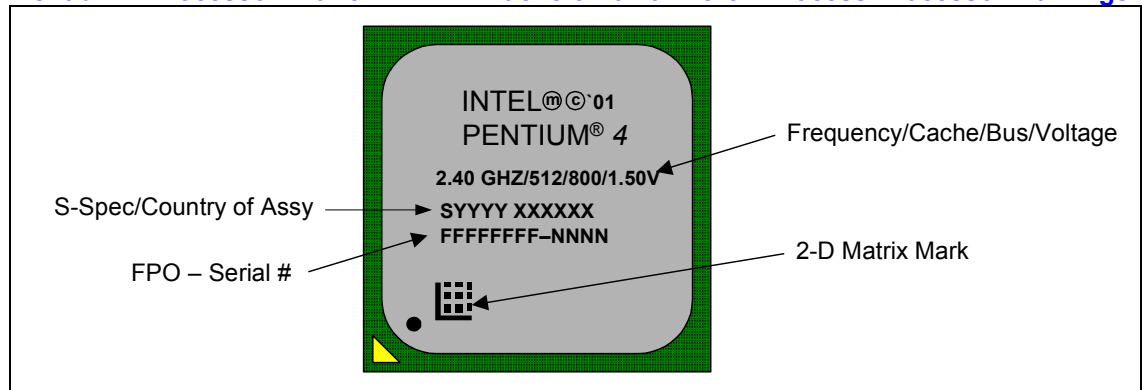
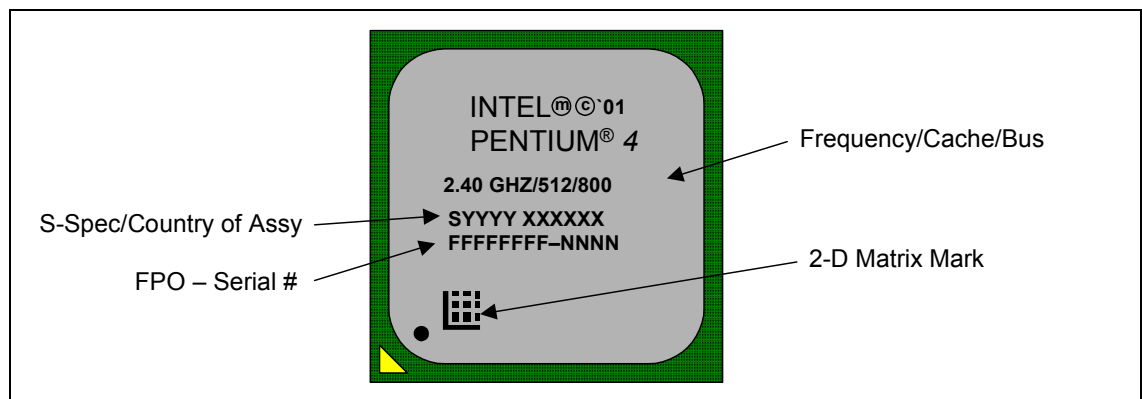
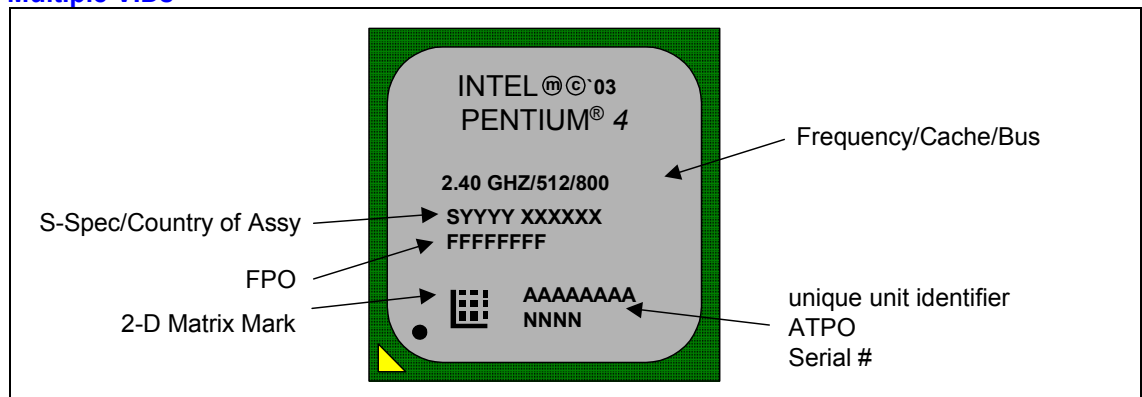


Figure 4. Multiple VIDs



Identification Information

The Pentium 4 processor may be identified by the following component markings:

Family ¹	Model ²	Brand ID ³
1111	0000	00001000
1111	0001	00001000 or 00001001
1111	0010	00001001

NOTES:

1. The Family corresponds to bits [11:8] of the EDX register after RESET, bits [11:8] of the EAX register after the CUID instruction is executed with a 1 in the EAX register, and the generation field of the Device ID register accessible through Boundary Scan.
2. The Model corresponds to bits [7:4] of the EDX register after RESET, bits [7:4] of the EAX register after the CUID instruction is executed with a 1 in the EAX register, and the model field of the Device ID register accessible through Boundary Scan.
3. The Brand ID corresponds to bits [7:0] of the EBX register after the CUID instruction is executed with a 1 in the EAX register.



Table 1. Intel® Pentium® 4 Processor Identification Information

S-Spec	Core Stepping	L2 Cache Size (bytes)	CPUID	Speed Core/Bus	Package and Revision	Notes
SL4QD	B2	256K	0F07h	1.30GHz/400MHz	31.0 mm OOI rev 1.0	1, 3
SL4SF	B2	256K	0F07h	1.30GHz/400MHz	31.0 mm OOI rev 1.0	3
SL4SG	B2	256K	0F07h	1.40GHz/400MHz	31.0 mm OOI rev 1.0	2, 3
SL4SC	B2	256K	0F07h	1.40GHz/400MHz	31.0 mm OOI rev 1.0	1, 3
SL4SH	B2	256K	0F07h	1.50GHz/400MHz	31.0 mm OOI rev 1.0	2, 3
SL4TY	B2	256K	0F07h	1.50GHz/400MHz	31.0 mm OOI rev 1.0	1, 3
SL5FW	C1	256K	0F0Ah	1.30GHz/400MHz	31.0 mm OOI rev 1.0	3
SL4WS	C1	256K	0F0Ah	1.40GHz/400MHz	31.0 mm OOI rev 1.0	3
SL4WT	C1	256K	0F0Ah	1.50GHz/400MHz	31.0 mm OOI rev 1.0	3
SL4WU	C1	256K	0F0Ah	1.60GHz/400MHz	31.0 mm OOI rev 1.0	3
SL57W	C1	256K	0F0Ah	1.7GHz/400MHz	31.0 mm OOI rev 1.0	2, 3
SL4WV	C1	256K	0F0Ah	1.80GHz/400MHz	31.0 mm OOI rev 1.0	3
SL5GC	C1	256K	0F0Ah	1.30GHz/400MHz	31.0 mm OOI rev 1.0	1, 3
SL4X2	C1	256K	0F0Ah	1.40GHz/400MHz	31.0 mm OOI rev 1.0	1, 3
SL4X3	C1	256K	0F0Ah	1.50GHz/400MHz	31.0 mm OOI rev 1.0	1, 3
SL4X4	C1	256K	0F0Ah	1.60GHz/400MHz	31.0 mm OOI rev 1.0	1, 3
SL57V	C1	256K	0F0Ah	1.70GHz/400MHz	31.0 mm OOI rev 1.0	1, 3
SL4X5	C1	256K	0F0Ah	1.80GHz/400MHz	31.0 mm OOI rev 1.0	1, 3
SL5SX	D0	256K	0F12h	1.50GHz/400MHz	31.0 mm FC rev 1.0	3
SL5VL	D0	256K	0F12h	1.60GHz/400MHz	31.0 mm FC rev 1.0	3
SL5SY	D0	256K	0F12h	1.70GHz/400MHz	31.0 mm FC rev 1.0	3
SL5VM	D0	256K	0F12h	1.80GHz/400MHz	31.0 mm FC rev 1.0	3
SL5VN	D0	256K	0F12h	1.90GHz/400MHz	31.0 mm FC rev 1.0	3
SL5SZ	D0	256K	0F12h	2GHz/400MHz	31.0 mm FC rev 1.0	3
SL5UL	D0	256K	0F12h	1.60GHz/400MHz	31.0 mm OOI rev 1.0	1, 3
SL5VM	D0	256K	0F12h	1.80GHz/400MHz	31.0 mm OOI rev 1.0	1, 3
SL5WH	D0	256K	0F12h	1.90GHz/400MHz	31.0 mm OOI rev 1.0	1, 3
SL5TQ	D0	256K	0F12h	2GHz/400MHz	31.0 mm OOI rev 1.0	1, 3
SL59U	C1	256K	0F0Ah	1.40GHz/400MHz	31.0 mm FC rev 1.0	2, 4
SL59V	C1	256K	0F0Ah	1.50GHz/400MHz	31.0 mm FC rev 1.0	4
SL5US	C1	256K	0F0Ah	1.60GHz/400MHz	31.0 mm FC rev 1.0	4
SL59X	C1	256K	0F0Ah	1.70GHz/400MHz	31.0 mm FC rev 1.0	4
SL5UT	C1	256K	0F0Ah	1.80GHz/400MHz	31.0 mm FC rev 1.0	4
SL5VK	D0	256K	0F12h	1.90GHz/400MHz	31.0 mm FC rev 1.0	4
SL5TG	D0	256K	0F12h	1.40GHz/400MHz	31.0 mm FC rev 1.0	2, 4
SL5TJ	D0	256K	0F12h	1.50GHz/400MHz	31.0 mm FC rev 1.0	2, 4
SL5VH	D0	256K	0F12h	1.60GHz/400MHz	31.0 mm FC rev 1.0	2, 4
SL5TK	D0	256K	0F12h	1.70GHz/400MHz	31.0 mm FC rev 1.0	2, 4
SL5VJ	D0	256K	0F12h	1.80GHz/400MHz	31.0 mm FC rev 1.0	2, 4
SL5VK	D0	256K	0F12h	1.90GHz/400MHz	31.0 mm FC rev 1.0	2, 4

S-Spec	Core Stepping	L2 Cache Size (bytes)	CPUID	Speed Core/Bus	Package and Revision	Notes
SL5TL	D0	256K	0F12h	2GHz/400MHz	31.0 mm FC rev 1.0	4
SL5N7	C1	256K	0F0Ah	1.40GHz/400MHz	31.0 mm FC rev 1.0	1, 4
SL5N8	C1	256K	0F0Ah	1.50GHz/400MHz	31.0 mm FC rev 1.0	1, 4
SL5UW	C1	256K	0F0Ah	1.60GHz/400MHz	31.0 mm FC rev 1.0	1, 4
SL5N9	C1	256K	0F0Ah	1.70GHz/400MHz	31.0 mm FC rev 1.0	1, 4
SL5UV	C1	256K	0F0Ah	1.80GHz/400MHz	31.0 mm FC rev 1.0	1, 4
SL5UE	D0	256K	0F12h	1.40GHz/400MHz	31.0 mm FC rev 1.0	1, 4
SL5UF	D0	256K	0F12h	1.50GHz/400MHz	31.0 mm FC rev 1.0	1, 4
SL62Y	D0	256K	0F12h	1.50GHz/400MHz	31.0 mm FC rev 1.0	1, 4, 6
SL5UJ	D0	256K	0F12h	1.60GHz/400MHz	31.0 mm FC rev 1.0	1, 4
SL5UG	D0	256K	0F12h	1.70GHz/400MHz	31.0 mm FC rev 1.0	1, 4
SL62Z	D0	256K	0F12h	1.70GHz/400MHz	31.0 mm FC rev 1.0	1, 4, 7
SL5UK	D0	256K	0F12h	1.80GHz/400MHz	31.0 mm FC rev 1.0	1, 4
SL5WG	D0	256K	0F12h	1.90GHz/400MHz	31.0 mm FC rev 1.0	1, 4
SL668	B0	512K	0F24	1.60GHz/400MHz	31.0 mm FC rev 1.0	1, 5, 8
SL63X	B0	512K	0F24	1.80GHz/400MHz	31.0 mm FC rev 1.0	1, 5, 9
SL62P	B0	512K	0F24	1.80GHz/400MHz	31.0 mm FC rev 1.0	2, 5, 7, 9
SL68Q	B0	512K	0F24	1.80GHz/400MHz	31.0 mm FC rev 1.0	1, 5
SL68R	B0	512K	0F24	2GHz/400MHz	31.0 mm FC rev 1.0	1, 5
SL5YR	B0	512K	0F24	2GHz/400MHz	31.0 mm FC rev 1.0	2, 5
SL5YS	B0	512K	0F24	2.20GHz/400MHz	31.0 mm FC rev 1.0	2, 5
SL68S	B0	512K	0F24	2.20GHz/400MHz	31.0 mm FC rev 1.0	1, 5
SL68T	B0	512K	0F24	2.40GHz/400MHz	31.0 mm FC rev 1.0	1, 5
SL5ZU	B0	512K	0F24	2.20GHz/400MHz	31.0 mm FC rev 1.0	1, 5
SL65R	B0	512K	0F24	2.40GHz/400MHz	31.0 mm FC rev 1.0	2, 5
SL67R	B0	512K	0F24	2.40GHz/400MHz	31.0 mm FC rev 1.0	1, 5
SL683	B0	512K	0F24	2.26GHz/533MHz	31.0 mm FC rev 1.0	1, 5
SL67Y	B0	512K	0F24	2.26GHz/533MHz	31.0 mm FC rev 1.0	2, 5
SL684	B0	512K	0F24	2.40GHz/533MHz	31.0 mm FC rev 1.0	1, 5
SL67Z	B0	512K	0F24	2.40GHz/533MHz	31.0 mm FC rev 1.0	2, 5
SL685	B0	512K	0F24	2.53GHz/533MHz	31.0 mm FC rev 1.0	1, 5
SL682	B0	512K	0F24	2.53GHz/533MHz	31.0 mm FC rev 1.0	2, 5
SL6HL	C1	512K	0F27	2.80GHz/533MHz	31.0 mm FC rev 1.0	5
SL6K6	C1	512K	0F27	2.80GHz/533MHz	31.0 mm FC rev 1.0	1, 5
SL6LA	C1	512K	0F27	1.80GHz/400MHz	31.0 mm FC rev 1.0	5
SL6GQ	C1	512K	0F27	2GHz/400MHz	31.0 mm FC rev 1.0	5
SL6GR	C1	512K	0F27	2.2GHz/400MHz	31.0 mm FC rev 1.0	5
SL6DU	C1	512K	0F27	2.26GHz/533MHz	31.0 mm FC rev 1.00	5
SL6EF	C1	512K	0F27	2.40GHz/533MHz	31.0 mm FC rev 1.0	1, 5
SL6DV	C1	512k	0F27	2.40GHz/533MHz	31.0 mm FC rev 1.0	2, 5
SL6EG	C1	512K	0F27	2.53GHz/533MHz	31.0 mm FC rev 1.0	1, 5



S-Spec	Core Stepping	L2 Cache Size (bytes)	CPUID	Speed Core/Bus	Package and Revision	Notes
SL6DW	C1	512K	0F27	2.53GHz/533MHz	31.0 mm FC rev 1.0	2, 5
SL6S6	C1	512K	0F27	1.80GHz/400MHz	31.0 mm FC rev 1.0	5, 16
SL6S7	C1	512K	0F27	2.00GHz/400MHz	31.0 mm FC rev 1.0	5, 16
SL6S8	C1	512K	0F27	2.20GHz/400MHz	31.0 mm FC rev 1.0	5, 16
SL6RY	C1	512K	0F27	2.26GHz/533MHz	31.0 mm FC rev 1.0	5, 16
SL6S9	C1	512K	0F27	2.40GHz/400MHz	31.0 mm FC rev 1.0	5, 16
SL6RZ	C1	512K	0F27	2.40GHz/533MHz	31.0 mm FC rev 1.0	5, 16
SL6SA	C1	512K	0F27	2.50GHz/400MHz	31.0 mm FC rev 1.0	5, 16
SL6S2	C1	512K	0F27	2.53GHz/533MHz	31.0 mm FC rev 1.0	5, 16
SL6SB	C1	512K	0F27	2.60GHz/400MHz	31.0 mm FC rev 1.0	5, 16
SL6S3	C1	512K	0F27	2.66GHz/533MHz	31.0 mm FC rev 1.0	5, 16
SL6S4	C1	512K	0F27	2.80GHz/533MHz	31.0 mm FC rev 1.0	5, 16
SL6S5	C1	512K	0F27	3.06GHz/533MHz	31.0 mm FC rev 1.0	5, 11, 16
SL5TN	D0	256K	0F12	1.50GHz/400MHz	31.0 mm FC rev 1.0	1, 3
SL4X5	C1	256K	0F0	1.80GHz/400MHz	31.0 mm FC rev 1.0	1, 3
SL6BC	E0	256K	0F13	1.60GHz/400MHz	31.0 mm FC rev 1.0	1, 4
SL679	E0	256K	0F13	1.60GHz/400MHz	31.0 mm FC rev 1.0	2, 4
SL6BD	E0	256K	0F13	1.70GHz/400MHz	31.0 mm FC rev 1.0	1, 4
SL67A	E0	256K	0F13	1.70GHz/400MHz	31.0 mm FC rev 1.0	2, 4
SL6BE	E0	256K	0F13	1.80GHz/400MHz	31.0 mm FC rev 1.0	1, 4
SL67B	E0	256K	0F13	1.80GHz/400MHz	31.0 mm FC rev 1.0	2, 4
SL6BF	E0	256K	0F13	1.90GHz/400MHz	31.0 mm FC rev 1.0	1, 4
SL67C	E0	256K	0F13	1.90GHz/400MHz	31.0 mm FC rev 1.0	2, 4
SL6E7	C1	512K	0F27	2GHz/400MHz	31.0 mm FC rev 1.0	1, 5
SL6E8	C1	512K	0F27	2.20GHz/400MHz	31.0 mm FC rev 1.0	1, 5
SL6EE	C1	512K	0F27	2.26GHz/533MHz	31.0 mm FC rev 1.0	1, 5
SL6E9	C1	512K	0F27	2.40GHz/533MHz	31.0 mm FC rev 1.0	1, 5
SL6SK	C1	512K	0F27	2.66GHz/533MHz	31.0 mm FC rev 1.0	1, 5, 16
SL6SL	C1	512K	0F27	2.80GHz/533MHz	31.0 mm FC rev 1.0	1, 5
SL6K7	C1	512K	0F27	3.06GHz/533MHz	31.0 mm FC rev 1.0	1, 5, 11
SL6SM	C1	512K	0F27	3.06GHz/533MHz	31.0 mm FC rev 1.0	1, 5, 11, 16
SL6JJ	C1	512K	0F27	3.06GHz/533MHz	31.0 mm FC rev 1.0	1, 5, 11
SL6QL	D1	512K	0F29	1.8GHz/400MHz	31.0 mm FC rev 1.0	1, 5, 9, 16
SL6QM	D1	512K	0F29	2.0GHz/400MHz	31.0 mm FC rev 1.0	1, 5, 16
SL6QN	D1	512K	0F29	2.2GHz/400MHz	31.0 mm FC rev 1.0	1, 5, 16
SL6QP	D1	512K	0F29	2.4GHz/400MHz	31.0 mm FC rev 1.0	1, 5, 16
SL6QQ	D1	512K	0F29	2.5GHz/400MHz	31.0 mm FC rev 1.0	1, 5, 16
SL6QR	D1	512K	0F29	2.6GHz/400MHz	31.0 mm FC rev 1.0	1, 5, 16
SL6Q7	D1	512K	0F29	2.26GHz/533MHz	31.0 mm FC rev 1.0	1, 5, 16
SL6Q8	D1	512K	0F29	2.4GHz/533MHz	31.0 mm FC rev 1.0	1, 5, 16

S-Spec	Core Stepping	L2 Cache Size (bytes)	CPUID	Speed Core/Bus	Package and Revision	Notes
SL6Q9	D1	512K	0F29	2.53GHz/533MHz	31.0 mm FC rev 1.0	1, 5, 16
SL6QA	D1	512K	0F29	2.66GHz/533MHz	31.0 mm FC rev 1.0	1, 5, 16
SL6QB	D1	512K	0F29	2.8GHz/533MHz	31.0 mm FC rev 1.0	1, 5, 16
SL6QC	D1	512K	0F29	3.06GHz/533MHz	31.0 mm FC rev 1.0	1, 5, 11, 16
SL6PM	D1	512K	0F29	2.40GHz/400MHz	31.0 mm FC rev 1.0	2, 5, 16
SL6PL	D1	512K	0F29	2.20GHz/400MHz	31.0 mm FC rev 1.0	2, 5, 16
SL6PK	D1	512K	0F29	2GHz/400MHz	31.0 mm FC rev 1.0	2, 5, 16
SL6PG	D1	512K	0F29	3.06GHz/533MHz	31.0 mm FC rev 1.0	2, 5, 11, 16
SL6PF	D1	512K	0F29	2.80GHz/533MHz	31.0 mm FC rev 1.0	2, 5, 16
SL6PE	D1	512K	0F29	2.66GHz/533MHz	31.0 mm FC rev 1.0	2, 5, 16
SL6PD	D1	512K	0F29	2.53GHz/533MHz	31.0 mm FC rev 1.0	2, 5, 16
SL6PC	D1	512K	0F29	2.40GHz/533MHz	31.0 mm FC rev 1.0	2, 5, 16
SL6PB	D1	512K	0F29	2.26GHz/533MHz	31.0 mm FC rev 1.0	2, 5, 16
SL6WU	D1	512K	0F29	3 GHz/800MHz	31.0 mm FC rev 1.0	1, 5, 11, 16
SL6WK	D1	512K	0F29	3 GHz/800MHz	31.0 mm FC rev 1.0	2, 5, 11, 16
SL6WF	D1	512K	0F29	2.40GHz/800MHz	31.0 mm FC rev 1.0	2, 5, 11, 16
SL6WH	D1	512K	0F29	2.60GHz/800MHz	31.0 mm FC rev 1.0	2, 5, 11, 16
SL6WJ	D1	512K	0F29	2.80GHz/800MHz	31.0 mm FC rev 1.0	2, 5, 11, 16
SL6WG	D1	512K	0F29	3.20GHz/800MHz	31.0 mm FC rev 1.0	2, 5, 11, 16
SL6WE	D1	512K	0F29	3.20GHz/800MHz	31.0 mm FC rev 1.0	1, 5, 11, 16
SL6WR	D1	512K	0F29	2.40GHz/800MHz	31.0 mm FC rev 1.0	1, 5, 11, 16
SL6WS	D1	512K	0F29	2.60GHz/800MHz	31.0 mm FC rev 1.0	1, 5, 11, 16
SL6WT	D1	512K	0F29	2.80GHz/800MHz	31.0 mm FC rev 1.0	1, 5, 11, 16

NOTES:

1. This is a boxed Intel Pentium 4 processor with an unattached fan heatsink.
2. These are tray precessors, but some are also offered as boxed processors with an unattached fan heatsink.
3. These processors are Pentium 4 processors in the 423-pin package.
4. These processors are Pentium 4 processors in the 478-pin package.
5. These processors are Pentium 4 processors with 512-KB L2 cache on 0.13 micron process.
6. These parts have some specifications that differ from those in the *Intel® Pentium® 4 Processor in the 478-pin Package datasheet*. The specifications that are different from the datasheet are: Vmax = 1.665 V, Vmin = 1.570 V, Icc_max = 46.1 A, TDP = 62.9 W, Tcase = 71 °C, Isgnt = 15.8 A.
7. These parts have some specifications that differ from those in the *Intel® Pentium® 4 Processor in the 478-pin Package datasheet*.. The specifications that are different from the datasheet are: Vmax = 1.655 V, Vmin = 1.560 V, Icc_max = 50.2 A, TDP = 67.7 W, Tcase = 73 °C, Isgnt = 16.1 A.
8. These parts have some specifications that differ from those in the *Intel® Pentium® 4 Processor with 512-KB L2 Cache on 0.13 Micron Process datasheet*. The specifications that are different from the datasheet are: Vmax= 1.425 V, Vmin=1.355 V, Icc_max = 38.8 A, TDP= 46.8W, Tcase= 66C, Isgnt=17.0 A.
9. These parts have some specifications that differ from those in the *Intel® Pentium® 4 Processor with 512-KB L2 Cache on 0.13 Micron Process datasheet*. The specifications that are different from the datasheet are: Vmax= 1.420 V, Vmin=1.350 V, Icc_max = 41.6 A, TDP= 49.6 W, Tcase= 67C, Isgnt=17.1 A.



10. These processors incorrectly return a Brand ID of 0Ah instead of the expected Brand ID of 09h. The Brand ID corresponds to bits [7:0] of the EBX register after the CPUID instruction is executed with a 1 in the EAX register.
11. These parts include Hyper-Threading Technology.
12. These parts are at VID=1.475 V.
13. These parts are at VID=1.500 V.
14. These parts are at VID=1.525 V.
15. These parts are at VID=1.550 V.
16. These parts have multiple VIDs.
17. These parts will only operate at the specified core to bus frequency ratio and lower.
18. These parts have some specifications that differ from those in the *Intel® Pentium® 4 Processor with 512-KB L2 Cache on 0.13 Micron Process Datasheet*. The specifications that are different from the datasheet are: Vmax = 1.420 V, Vmin = 1.330 V, Icc_max = 69.0 A, TDP = 86.6 W, Tcase = 68 °C, Isgnt = 31.0 A.
19. These parts have some specifications that differ from those in the *Intel® Pentium® 4 Processor with 512-KB L2 Cache on 0.13 Micron Process Datasheet*. The specifications that are different from the datasheet are: Vmax = 1.425 V, Vmin = 1.350 V, Icc_max = 57.9 A, TDP = 75.1 W, Tcase = 72 °C, Isgnt = 32.0 A.
20. These parts have some specifications that differ from those in the *Intel® Pentium® 4 Processor with 512-KB L2 Cache on 0.13 Micron Process Datasheet*. The specifications that are different from the datasheet are: Vmax = 1.420 V, Vmin = 1.340 V, Icc_max = 60.5 A, TDP = 78.0 W, Tcase = 74 °C, Isgnt = 32.0 A.
21. Intel Pentium(R) 4 processor with 512KB L2 cache on .13 Micron Process M-0 stepping is a unique and independent stepping of Intel Pentium(R) 4 processors.

Summary Table of Changes

The following table indicates the Errata, Documentation Changes, Specification Clarifications, or Specification Changes that apply to Intel Pentium 4 processors. Intel intends to fix some of the errata in a future stepping of the component, and to account for the other outstanding issues through documentation or specification changes as noted. This table uses the following notations:

Codes Used in Summary Table

Stepping

X: Erratum, Specification Change or Clarification that applies to this stepping.

(No mark) or (Blank Box): This erratum is fixed in listed stepping or specification change does not apply to listed stepping.

Status

Doc: Document change or update that will be implemented.

PlanFix: This erratum may be fixed in a future stepping of the product.

Fixed: This erratum has been previously fixed.

NoFix: There are no plans to fix this erratum.

PKG: This column refers to errata on the the Intel® Pentium® 4 processor substrate.

AP: APIC related erratum.

Shaded: This item is either new or modified from the previous version of the document.

Note: Each Specification Update item is prefixed with a capital letter to distinguish the product. The key below details the letters that are used in Intel's microprocessor Specification Updates:

A = Intel® Pentium® II processor

B = Mobile Intel® Pentium® II processor

C = Intel® Celeron® processor

D = Intel® Pentium® II Xeon™ processor

E = Intel® Pentium® III processor

G = Intel® Pentium® III Xeon™ processor

H = Mobile Intel® Celeron® processor at 466 MHz, 433 MHz, 400 MHz, 366 MHz, 333 MHz, 300 MHz, and 266 MHz

K = Mobile Intel® Pentium® III Processor - M

M = Mobile Intel® Celeron® processor

N = Intel® Pentium® 4 processor

O = Intel® Xeon™ processor MP

P = Intel® Xeon™ processor

T = Mobile Intel® Pentium® 4 processor – M

V = Intel® Celeron® processor in the 478-Pin Package

W = Low Voltage Intel® Xeon™ processor

Z = Mobile Intel® Pentium® 4 Processor with 533 MHz System Bus

NO.	B2	C1	D0	E0	nB0	nC1	D1	Plans	ERRATA
N1	X	X	X	X	X	X	X	NoFix	I/O restart in SMM may fail after simultaneous machine check exception (MCE)
N2	X	X	X	X	X	X	X	NoFix	MCA registers may contain invalid information if RESET# occurs and PWRGOOD is not held asserted
N3	X	X	X	X				Fixed	Uncacheable (UC) code in same line as write back (WB) data may lead to data corruption
N4	X	X	X	X	X	X	X	NoFix	Transaction is not retried after BINIT#
N5	X	X	X	X	X	X	X	NoFix	Invalid opcode 0FFFh requires a ModRM byte
N6	X							Fixed	RFO-ECC-snoop-MCA combination can result in two lines being corrupted in main memory
N7	X							Fixed	Overlap of MTRRs with the same memory type results in a type of uncacheable (UC)
N8	X	X	X	X	X	X	X	NoFix	FSW may not be completely restored after page fault on FRSTOR or FLDENV instructions
N9	X	X	X	X	X	X	X	NoFix	The processor flags #PF instead of #AC on an unlocked CMPXCHG8B instruction
N10	X							Fixed	IERR# may not go active when an internal error occurs
N11	X							Fixed	All L2 cache uncorrectable errors are logged as data writes
N12	X	X	X	X	X	X	X	NoFix	When in no-fill mode the memory type of large pages are incorrectly forced to uncacheable
N13	X	X	X	X	X	X	X	No Fix	Processor may hang due to speculative page walks to non-existent system memory
N14	X							Fixed	Load operations may get stale data in the presence of memory address aliasing
N15	X	X	X	X				Fixed	Writing a performance counter may result in incorrect value
N16	X	X	X	X	X	X	X	NoFix	IA32_MC0_STATUS register overflow bit not set correctly
N17	X	X	X	X				Fixed	Performance counter may contain incorrect value after being stopped
N18	X							Fixed	The TAP drops the last bit during instruction register shifting
N19	X							Fixed	Data breakpoints on the high half of a floating point line split may not be captured
N20	X	X	X	X				Fixed	MCA error code field in IA32_MC0_STATUS register may become out of sync with the rest of the register
N21	X							Fixed	Processor may hang on a correctable error and snoop combination
N22	X	X	X	X	X	X	X	NoFix	The IA32_MC1_STATUS register may contain incorrect information for correctable errors
N23	X							Fixed	MCA error incorrectly logged as prefetches

NO.	B2	C1	D0	E0	nB0	nC1	D1	Plans	ERRATA
N24	X							Fixed	Speculative loads which hit the L2 cache and get an uncorrectable error will log erroneous information
N25	X							Fixed	Processor may fetch reset vector from cache if A20M# is asserted during init
N26	X							Fixed	A correctable error on an L2 cache shared state line hit with go to invalid snoop hangs processor
N27	X							Fixed	System hang due to uncorrectable error and bus lock combination
N28	X							Fixed	Incorrect address for an L1 tag parity error is logged in IA32_MC1_ADDR register
N29	X	X						Fixed	REP MOV instruction with overlapping source and destination may result in data corruption
N30	X							Fixed	Stale data in processor translation cache may result in hang
N31	X							Fixed	I/O buffers for FERR#, PROCHOT# and THERMTRIP# are not AGTL+
N32	X							Fixed	RFO and correctable error combination may cause lost store or hang
N33	X							Fixed	RFO and correctable error may incorrectly signal the machine check handler
N34	X							Fixed	Processor may report invalid TSS fault instead of double fault during mode C paging
N35	X							Fixed	IA32_MC0_STATUS incorrect after illegal APIC request
N36	X	X						Fixed	Thermal status log bit may not be set when the thermal control circuit is active
N37	X	X	X	X	X	X	X	NoFix	Debug mechanisms may not function as expected
N38	X	X	X	X	X	X	X	NoFix	Machine check architecture error reporting and recovery may not work as expected
N39	X	X	X	X				Fixed	Processor may Timeout Waiting for a Device to Respond after ~0.67 Seconds
N40	X	X	X	X	X	X	X	NoFix	Cascading of Performance Counters does not work Correctly when Forced Overflow is Enabled
N41	X							Fixed	Possible Machine Check Due to Line-Split Loads with Page-Tables in Uncacheable (UC) Space
N42	X	X	X	X				Fixed	IA32_MC1_STATUS MSR ADDRESS VALID bit may be set when no Valid Address is Available
N43	X	X	X	X	X	X	X	NoFix	EMON event counting of x87 loads may not work as expected
N44	X	X	X	X				Fixed	Software controlled clock modulation using a 12.5% or 25% duty cycle may cause the processor to hang
N45	X	X						Fixed	Speculative page fault may cause livelock
N46	X	X						Fixed	PAT index MSB may be calculated incorrectly
N47		X	X	X				Fixed	SQRTPD and SQRTSD may return QNaN indefinite instead of negative zero

NO.	B2	C1	D0	E0	nB0	nC1	D1	Plans	ERRATA
N48	X	X	X	X				Fixed	Bus invalidate line requests that return unexpected data may result in L1 cache corruption
N49	X	X	X	X				Fixed	Write Combining (WC) load may result in unintended address on system bus
N50	X	X	X	X	X			Fixed	Incorrect data may be returned when page tables are in Write Combining (WC) memory space
N51		X	X	X				PlanFix	Buffer on resistance may exceed specification
N52	X	X	X	X	X	X	X	NoFix	Processor issues inconsistent transaction size attributes for locked operation
N53	X	X	X	X	X			Fixed	Multiple accesses to the same S-state L2 cache line and ECC error combination may result in loss of cache coherency
N54	X	X	X	X				Fixed	Processor may hang when resuming from Deep Sleep state
N55	X	X	X	X	X	X	X	NoFix	When the processor is in the System Management Mode (SMM), debug registers may be fully writeable
N56	X	X	X	X	X	X	X	NoFix	Associated counting logic must be configured when using Event Selection Control (ESCR) MSR
N57	X	X	X	X	X	X	X	NoFix	IA32_MC0_ADDR and IA32_MC0_MISC registers will contain invalid or stale data following a Data, Address, or Response Parity Error
N58	X	X	X	X	X			Fixed	CR2 may be incorrect or an incorrect page fault error code may be pushed onto stack after execution of an LSS instruction
N59					X			Fixed	BPM[5:3]# V _{IL} does not meet specification
N60					X	X	X	NoFix	Processor may hang under certain frequencies and 12.5% STPCLK# duty cycle
N61	X	X	X	X	X	X	X	NoFix	System may hang if a fatal cache error causes Bus Write Line (BWL) transaction to occur to the same cache line address as an outstanding Bus Read Line (BRL) or Bus Read-Invalidate Line (BRIL)
N62	X	X	X	X	X			Fixed	L2 cache may contain stale data in the Exclusive state
N63	X	X	X	X	X	X		Fixed	Re-mapping the APIC base address to a value less than or equal to 0xDC001000 may cause IO and Special Cycle failure
N64				X	X	X		Fixed	Erroneous BIST result found in EAX register after reset
N65	X	X	X	X	X			Fixed	Processor does not flag #GP on non-zero write to certain MSRs
N66	X	X	X	X	X	X	X	No Fix	Simultaneous assertion of A20M# and INIT# may result in incorrect data fetch
N67	X	X	X	X	X			Fixed	CPUID instruction returns incorrect number of ITLB entries
N68	X	X	X	X	X	X	X	No Fix	A Write to APIC Registers Sometimes May Appear to Have Not Occurred
N69						X	X	No Fix	Missing Stop-clock Acknowledge from the Processor

NO.	B2	C1	D0	E0	nB0	nC1	D1	Plans	ERRATA
N70						X		Fixed	Store to Load Data Forwarding May Result in Switched Data Bytes
N71					X	X	X	No Fix	Parity Error in the L1 Cache may Cause the Processor to Hang
N72					X	X		Fixed	The TCK Input in the Test Access Port (TAP) is Sensitive to Low Clock Edge Rates and Prone to Noise Coupling Onto TCK's Rising or Falling Edges
N73						X	X	No Fix	Disabling a Local APIC Disables Both Logical Processor APICs on a Hyper-Threading Technology Enabled Processor
N74							X	Plan Fix	A circuit marginality in the 800 MHz Front Side Bus power save circuitry may cause a system and/or application hang or may result in incorrect data
N75						X	X	No Fix	Using STPCLK and Executing Code From Very Slow Memory Could Lead to a System Hang
N76			X	X				No Fix	Changes to CR3 Register do not Fence Pending Instruction Page Walks
N77	X	X	X	X	X	X	X	No Fix	The State of the Resume Flag (RF Flag) in a Task-State Segment (TSS) May be Incorrect

Number	SPECIFICATION CHANGES
N1	PWRGOOD Specification Changes

Number	SPECIFICATION CLARIFICATIONS
N1	Clarifying DBI# Definition for All Processors with Intel® NetBurst™ Microarchitecture
N2	Thermal Specification Clarification

Number	DOCUMENTATION CHANGES
	There are no Documentation Changes in this Specification Update revision.

Errata

N1. I/O Restart in SMM May Fail after Simultaneous Machine Check Exception (MCE)

Problem: If an I/O instruction (IN, INS, REP INS, OUT, OUTS, or REP OUTS) is being executed, and if the data for this instruction becomes corrupted, the processor will signal a Machine Check Exception (MCE). If the instruction is directed at a device that is powered down, the processor may also receive an assertion of SMI#. Since MCEs have higher priority, the processor will call the MCE handler, and the SMI# assertion will remain pending. However, upon attempting to execute the first instruction of the MCE handler, the SMI# will be recognized and the processor will attempt to execute the SMM handler. If the SMM handler is completed successfully, it will attempt to restart the I/O instruction, but will not have the correct machine state, due to the call to the MCE handler.

Implication: A simultaneous MCE and SMI# assertion may occur for one of the I/O instructions above. The SMM handler may attempt to restart such an I/O instruction, but will have an incorrect state due to the MCE handler call, leading to failure of the restart and shutdown of the processor.

Workaround: If a system implementation must support both SMM and board I/O restart, the first thing the SMM handler code should do is check for a pending MCE. If there is an MCE pending, the SMM handler should immediately exit via an RSM instruction and allow the MCE handler to execute. If there is no MCE pending, the SMM handler may proceed with its normal operation.

Status: For the steppings affected, see the *Summary Table of Changes*.

N2. MCA Registers May Contain Invalid Information If RESET# Occurs and PWRGOOD Is Not Held Asserted

Problem: This erratum can occur as a result either of the following events:

- PWRGOOD is de-asserted during a RESET# assertion causing internal glitches that may result in the possibility that the MCA registers latch invalid information.
- Or during a reset sequence if the processor's power remains valid regardless of the state of PWRGOOD, and RESET# is re-asserted before the processor has cleared the MCA registers, the processor will begin the reset process again but may not clear these registers.

Implication: When this erratum occurs, the information in the MCA registers may not be reliable.

Workaround: Ensure that PWRGOOD remains asserted throughout any RESET# assertion and that RESET# is not re-asserted while PWRGOOD is de-asserted.

Status: For the steppings affected, see the *Summary Table of Changes*.

N3. Uncacheable (UC) Code in Same Line As Write Back (WB) Data May Lead to Data Corruption

Problem: When both code (being accessed as UC or WC) and data (being accessed as WB) are aliased into the same cache line, the UC fetch will cause the processor to self-snoop and generate an implicit writeback. The data supplied by this implicit writeback may be corrupted due to the way the processor handles self-modifying code.

Implication: UC or WC code located in the same cache line as WB data may lead to data corruption.

Workaround: UC or WC code should not be located in the same physical 64 byte cache line as any location that is being stored to with WB data.

Status: For the steppings affected, see the *Summary Table of Changes*.

N4. Transaction Is Not Retried after BINIT#

Problem: If the first transaction of a locked sequence receives a HITM# and DEFER# during the snoop phase it should be retried and the locked sequence restarted. However, if BINIT# is also asserted during this transaction, it will not be retried.

Implication: When this erratum occurs, locked transactions will unexpectedly not be retried.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N5. Invalid Opcode 0FFFh Requires a ModRM Byte

Problem: Some invalid opcodes require a ModRM byte (or other following bytes), while others do not. The invalid opcode 0FFFh did not require a ModRM byte in previous generation Intel architecture processors, but does in the Pentium 4 processor.

Implication: The use of an invalid opcode 0FFFh without the ModRM byte may result in a page or limit fault on the Pentium 4 processor.

Workaround: Use a ModRM byte with invalid 0FFFh opcode.

Status: For the steppings affected, see the *Summary Table of Changes*.

N6. RFO-ECC-Snoop-MCA Combination Can Result in Two Lines Being Corrupted in Main Memory

Problem: When a snoop comes into the processor between global observation and data return for a Read-for-Ownership (RFO) request that hits an E or M state in the L2 cache that contains a correctable error, two lines in system memory may be corrupted. One of the corrupted lines is the one that contained the correctable error. The second corrupted line is unrelated to the first line. When a snoop comes into the processor between global observation and data return for a Read-for-Ownership (RFO) request that hits an E or M state in the L2 cache that contains a correctable error, two lines in system memory may be corrupted. One of the corrupted lines is the one that contained the correctable error. The second corrupted line is unrelated to the first line

Implication: When this erratum occurs, system and cache memory may be corrupted.

Workaround: While there is no workaround to prevent the second line from being corrupted, avoiding tight data sharing and tight spin loops will reduce the possibility of this erratum occurring. Tight spins loops can be avoided by inserting the PAUSE instruction into the loop.

Status: For the steppings affected, see the *Summary Table of Changes*.

N7. Overlap of MTRRs with the Same Memory Type Results in a Type of Uncacheable (UC)

Problem: If two or more variable memory type range registers overlap, both with memory type X (where X is WB, WT, or WC), the resulting memory type for the overlap range will be UC instead of the more logical memory type X.

Implication: When this erratum occurs, a potentially significant performance decrease may occur for accesses to these memory ranges since the memory type has been translated to UC.

Workaround: Intel does not support the overlapping of any two or more MTRRs unless one of them is of UC memory type. Ensure that the system BIOS does not create overlapping memory ranges.

Status: For the steppings affected, see the *Summary Table of Changes*.

N8. FSW May Not Be Completely Restored after Page Fault on FRSTOR or FLDENV Instructions

Problem: If the FPU operating environment or FPU state (operating environment and register stack) being loaded by an FLDENV or FRSTOR instruction wraps around a 64-KB or 4-GB boundary and a page fault (#PF) or segment limit fault (#GP or #SS) occurs on the instruction near the wrap boundary, the upper byte of the FPU status word (FSW) might not be restored. If the fault handler does not restart program execution at the faulting instruction, stale data may exist in the FSW.

Implication: When this erratum occurs, stale data will exist in the FSW.

Workaround: Ensure that the FPU operating environment and FPU state do not cross 64-KB or 4-GB boundaries. Alternately, ensure that the page fault handler restarts program execution at the faulting instruction after correcting the paging problem.

Status: For the steppings affected, see the *Summary Table of Changes*.

N9. The Processor Flags #PF Instead of #AC on an Unlocked CMPXCHG8B Instruction

Problem: If a data page fault (#PF) and alignment check fault (#AC) both occur for an unlocked CMPXCHG8B instruction, then #PF will be flagged.

Implication: Software that depends #AC before #PF will be affected since #PF is flagged in this case.

Workaround: Remove the software's dependency on the fact that #AC has precedence over #PF. Alternately, reload the page in the page fault handler and then restart the faulting instruction

Status: For the steppings affected, see the *Summary Table of Changes*.

N10. IERR# May Not go Active When an Internal Error Occurs

Problem: If the processor hangs because a store to the system bus does not complete, the processor may not assert the IERR# signal.

Implication: When this erratum occurs, IERR# is not signaled.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N11. All L2 Cache Uncorrectable Errors Are Logged As Data Writes

Problem: When a Data Read operation which hits the L2 cache gets an uncorrectable error, the processor should log this error in the IA32_MC1_STATUS register as a Data Read by setting bits 7-4 to 0011b. The processor incorrectly logs Data Read operations, which hit the L2 cache and receive an uncorrectable error, with the bit pattern 0100b, indicating a Data Write Operation.

Implication: Data Read operations, which cause an uncorrectable error, are logged as Data Write operations.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N12. When in No-Fill Mode the Memory Type of Large Pages Are Incorrectly Forced to Uncacheable

Problem: When the processor is operating in No-Fill Mode (CR0.CD=1), the paging hardware incorrectly forces the memory type of large (PSE-4M and PAE-2M) pages to uncacheable (UC) memory type regardless of the MTRR settings. By forcing the memory type of these pages to UC, load operations, which should hit valid data in the L1 cache, are forced to load the data from system memory. Some applications will lose the performance advantage associated with the caching permitted by other memory types.

Implication: This erratum may result in some performance degradation when using no-fill mode with large pages.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.



N13. Processor May Hang Due to Speculative Page Walks to Non-Existent System Memory

Problem: A load operation that misses the Data Translation Lookaside Buffer (DTLB) will result in a page-walk. If the page-walk loads the Page Directory Entry (PDE) from cacheable memory and that PDE load returns data that points to a valid Page Table Entry (PTE) in uncacheable memory the processor will access the address referenced by the PTE. If the address referenced does not exist the processor will hang with no response from system memory.

Implication: Processor may hang due to speculative page walks to non-existent system memory.

Workaround: Page directories and page tables in UC memory space which are marked valid must point to physical addresses that will return a data response to the processor.

Status: For the steppings affected, see the *Summary Table of Changes*.

N14. Load Operations May Get Stale Data in the Presence of Memory Address Aliasing

Problem: Aliasing refers to multiple logical addresses referencing the same physical address in memory. When multiple stores to the same physical memory location are pending in the processor, the processor must ensure that a subsequent instruction, which loads data from that same physical memory location, receives the data from the most recent store. When there are two pending stores in the processor to the same physical memory address, and the more recent store uses a different logical address to reference the same physical address, it is possible that a subsequent load from the same physical address may incorrectly receive the data based on the older store, rather than the most recently executed store.

Implication: When this erratum occurs, stale data will be loaded.

Workaround: It is possible for the BIOS to contain a workaround for this erratum.

Status: For the steppings affected, see the *Summary Table of Changes*.

N15. Writing a Performance Counter May Result in Incorrect Value

Problem: When a performance counter is written and the event counter for the event being monitored is non-zero, the performance counter will be incremented by the value on that event counter. Because the upper eight bits of the performance counter are not written at the same time as the lower 32 bits, the increment due to the non-zero event counter may cause a carry to the upper bits such that the performance counter contains a value about four billion (2^{32}) higher than what was written.

Implication: When this erratum occurs, the performance counter will contain a different value from that which was written.

Workaround: If the performance counter is set to select a null event and the counter configuration and control register (CCCR) for that counter has its compare bit set to zero, before the performance counter is written, this erratum will not occur. Since the lower 32 bits will always be correct, event counting which does not exceed 2^{32} events will not be affected.

Status: For the steppings affected, see the *Summary Table of Changes*.

N16. IA32_MC0_STATUS Register Overflow Bit Not Set Correctly

Problem: The Overflow Error bit (bit 62) in the IA32_MC0_STATUS register indicates, when set, that a machine check error occurred while the results of a previous error were still in the error reporting bank (i.e. the valid bit was set when the new error occurred). In the case of this erratum, if an uncorrectable error is logged in the error-reporting bank and another error occurs, the overflow bit will not be set.

Implication: When this erratum occurs the overflow bit will not be set.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N17. Performance Counter May Contain Incorrect Value after Being Stopped

Problem: If a performance counter is stopped on the precise internal clock cycle where the intermediate carry from the lower 32 bits of the counter to the upper eight bits occurs, the intermediate carry is lost.

Implication: When this erratum occurs, the performance counter will contain a value about 4 billion (2^{32}) less than it should.

Workaround: Since this erratum does not occur if the performance counters are read when running, a possible workaround is to read the counter before stopping it. Since the lower 32 bits will always be correct, event counting which does not exceed 2^{32} events will not be affected.

Status: For the steppings affected, see the *Summary Table of Changes*.

N18. The TAP Drops the Last Bit during Instruction Register Shifting

Problem: While shifting in new opcode bits during the Shift-IR state, the test access port (TAP) should shift out, via the TDO pin, a 1 followed by enough 0s to fill up the rest of the opcode length. Since the processor TAP has 7 opcode bits, it should shift out 0000001. The TAP stops driving on the same TAP clock edge that the receiver samples, with the result that 0000001 or 1000001 might be observed.

Implication: The last bit may be incorrect during instruction register shifting.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N19. Data Breakpoints on the High Half of a Floating Point Line Split May Not Be Captured

Problem: When a floating point load which splits a 64-byte cache line gets a floating point stack fault, and a data breakpoint register maps to the high line of the floating point load, internal boundary conditions exist that may prevent the data breakpoint from being captured.

Implication: When this erratum occurs, a data breakpoint will not be captured.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.



N20. MCA Error Code Field in IA32_MC0_STATUS Register May become out of Sync with the Rest of the Register

Problem: The MCA Error Code field of the IA32_MC0_STATUS register gets written by a different mechanism than the rest of the register. For uncorrectable errors, the other fields in the IA32_MC0_STATUS register are only updated by the first error. Any subsequent errors cause the Overflow Error bit to be asserted until this register is cleared. Because of this erratum, any further errors that are detected will update the MCA Error Code field without updating the rest of the register, thereby leaving the IA32_MC0_STATUS register with stale information.

Implication: When this erratum occurs, the IA32_MC0_STATUS register contains stale information.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N21. Processor May Hang on a Correctable Error and Snoop Combination

Problem: The processor will hang whenever a Read-For-Ownership (RFO) or Locked-Read-For-Ownership (LRFO) hits a line in the L2 cache and also receives a correctable error. A boundary condition in the error correction logic prevents the processor from issuing further transactions on the system bus and the processor will hang

Implication: When this erratum occurs, the processor may hang.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N22. The IA32_MC1_STATUS Register May Contain Incorrect Information for Correctable Errors

Problem: When a speculative load operation hits the L2 cache and receives a correctable error, the IA32_MC1_STATUS register may be updated with incorrect information. The IA32_MC1_STATUS register should not be updated for speculative loads.

Implication: When this erratum occurs, the IA32_MC1_STATUS register will contain incorrect information for correctable errors.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N23. MCA Error Incorrectly Logged As Prefetches

Problem: An MCA error is being incorrectly logged as PREFETCH type errors in the Request sub-field of the Compound error code in the IA32_MC0_STATUS register. A store, which hits a double bit data error in the L2 cache, is incorrectly logged as a prefetch data error

Implication: When this erratum occurs, the IA32_MC0_STATUS register will contain incorrect information.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N24. Speculative Loads Which Hit the L2 cache and Get an Uncorrectable Error Will Log Erroneous Information

Problem: If a speculative load that hits the L2 cache and has an uncorrectable error, the load is subsequently cancelled, but the processor will still report that it has received an uncorrectable error via bit 61 of the IA32_MC1_STATUS register. Any other information in this register will not be associated with this uncorrectable error and is therefore erroneous.

Implication: When this erratum occurs, erroneous information is logged in the IA32_MC1_STATUS register.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N25. Processor May Fetch Reset Vector from Cache if A20M# is Asserted during Init

Problem: If A20M# is asserted with INIT# or after INIT# but before the first code fetch occurs, then the processor should fetch the reset vector from the system bus but instead may fetch the vector from cache.

Implication: Instead of forcing the fetch from the bus, the processor may fetch the reset vector from cache.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N26. A Correctable Error on an L2 Cache Shared State Line Hit with go to Invalid Snoop Hangs Processor

Problem: When the following events occur:

- A read for ownership (RFO) is issued by the processor and hits a line in Shared (S) state in the L2 cache,
- The operation also receives a correctable error on the data that is read, and
- At the same time the RFO is accessing the cache, it is hit by Go to Invalid snoop,

The snoop makes the RFO appear to have missed cache. Although the RFO appears to have missed the cache, the ECC error code is not cleared and the L2 cache control logic fails to communicate that the RFO has completed. The processor does not see that the RFO has completed and will hang.

Implication: When this erratum occurs, the processor will hang. Intel has not been able to reproduce this erratum with commercial software.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N27. System Hang Due to Uncorrectable Error and Bus Lock Combination

Problem: When the following events occur:

- The L2 cache receives a speculative load request from the processor just as it is starting to process a split load lock,
- The speculative load gets cancelled but only after it receives an uncorrectable error, and
- Bus Lock is asserted for the split load lock and the first half of the split load lock goes out on the system bus,

The first half of the load completes, but the uncorrectable error seen earlier prevents the dispatch of the second half of the split load lock and the processor will hang with lock asserted.

Implication: When this erratum occurs, the processor will hang.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N28. Incorrect Address for an L1 Tag Parity Error Is Logged in IA32_MC1_ADDR Register

Problem: The address of an L1 tag parity error is latched one clock cycle too late resulting in the wrong address being logged in IA32_MC1_ADDR register.

Implication: When this erratum occurs, the wrong address may be logged in IA32_MC1_ADDR register in response to an L1 tag parity error.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N29. REP MOV Instruction with Overlapping Source and Destination May Result in Data Corruption

Problem: When fast strings are enabled and a REP MOV instruction is used to move a string and the source and destination strings overlap by 56 bytes or less, data corruption may occur.

Implication: When this erratum occurs, data corruption may occur

Workaround: It is possible for the BIOS to contain a workaround for this erratum.

Status: For the steppings affected, see the *Summary Table of Changes*.

N30. Stale Data in Processor Translation Cache May Result in Hang

Problem: Several instructions and task switches normally invalidate the processor translation cache. Under an internal boundary condition these instructions or task switches may not completely invalidate the processor translation cache.

Implication: When this erratum occurs, subsequent processor load and store operations may use stale translations leading to unpredictable results

Workaround: It is possible for BIOS code to contain a workaround for this erratum.

Status: For the steppings affected, see the *Summary Table of Changes*.

N31. I/O Buffers for FERR#, PROCHOT# and THERMTRIP# Are Not AGTL+

Problem: The I/O buffers for the FERR#, PROCHOT# and THERMTRIP# signals are specified in the *Intel® Pentium® 4 Processor in the 423-pin Package Datasheet* as AGTL+ buffers. The buffers for these signals were instead designed with CMOS buffers.

Implication: It is not expected that any platforms will be affected by this erratum.

Workaround: None necessary

Status: For the steppings affected, see the *Summary Table of Changes*.

N32. RFO and Correctable Error Combination May Cause Lost Store or Hang

Problem: The processor may lose a store operation or the system may hang in the following scenario:

- Error reporting is not enabled in the IA32_MC1_CTL register, and
- The processor issues a Read for Ownership (RFO) that hits an L2 cache line in the Exclusive or Modified state.
- This RFO access receives a correctable error that occurs at the same time this cache line is hit by an external snoop.

Implication: When this erratum occurs a store operation will be lost, or the system will hang. This erratum has only been observed in a focused testing environment.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N33. RFO and Correctable Error May Incorrectly Signal the Machine Check Handler

Problem: The processor may incorrectly go to the Machine Check handler in the following scenario:

- Error reporting is enabled in the IA32_MC1_CTL register,
- The processor issues a Read for Ownership (RFO) that hits an L2 cache line in the Shared state, and
- This RFO access also receives a correctable error.
- An external snoop hits the same cacheline immediately after the RFO.

Implication: When this erratum occurs, the processor will incorrectly enter the machine check handler. A correctable error will also be reported in the IA32_MC1_STATUS and IA32_MC0_STATUS registers. This erratum has only been observed in a focused testing environment.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N34. Processor May Report Invalid TSS Fault Instead of Double Fault during Mode C Paging

Problem: When an operating system executes a task switch via a Task State Segment (TSS) the CR3 register is always updated from the new task TSS. In the mode C paging, once the CR3 is changed the processor will attempt to load the PDPTRs. If the CR3 from the target task TSS or task switch handler TSS is not valid then the new PDPTR will not be loaded. This will lead to the reporting of invalid TSS fault instead of the expected Double fault.

Implication: Operating systems that access an invalid TSS may get invalid TSS fault instead of a Double fault.

Workaround: Software needs to ensure any accessed TSS is valid.

Status: For the steppings affected, see the *Summary Table of Changes*.

N35. IA32_MC0_STATUS Incorrect after Illegal APIC Request

Problem: When an invalid APIC access error is logged in the IA32_MC0_STATUS register, the value returned should indicate a complex bus and interconnect error but instead indicates a complex memory hierarchy error.

Implication: When this erratum occurs, the IA32_MC0_STATUS register will contain incorrect information.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N36. Thermal Status Log Bit May Not Be Set When the Thermal Control Circuit Is Active

Problem: Bit 1 of the IA32_THERM_STATUS register (Thermal Status Log) is a sticky bit designed to be set to '1' if the thermal control circuit (TCC) has been active since either the previous processor reset or software cleared this bit. If TCC is active and the Thermal Status Log bit is cleared by a processor reset or by software, it will remain clear (set to '0') as long as the TCC remains active. Once TCC deactivates, the next activation of the TCC will set the Thermal Status Log bit.

Implication: When this erratum occurs, the Thermal Status Log bit remains cleared (set to '0') although the thermal control circuit is active.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N37. Debug Mechanisms May Not Function As Expected

Problem: Certain debug mechanisms may not function as expected on the processor. The cases are as follows:

- When the following conditions occur: 1) An FLD instruction signals a stack overflow or underflow, 2) the FLD instruction splits a page-boundary or a 64 byte cache line boundary, 3) the instruction matches a Debug Register on the high page or cache line respectively, and 4) the FLD has a stack fault and a memory fault on a split access, the processor will only signal the stack fault and the debug exception will not be taken.
- When a data breakpoint is set on the ninth and/or tenth byte(s) of a floating point store using the Extended Real data type, and an unmasked floating point exception occurs on the store, the breakpoint will not be captured.
- When any instruction has multiple debug register matches, and any one of those debug registers is enabled in DR7, all of the matches should be reported in DR6 when the processor goes to the debug handler. This is not true during a REP instruction. As an example, during execution of a REP MOVSW instruction the first iteration a load matches DR0 and DR2 and sets DR6 as FFFF0FF5h. On a subsequent iteration of the instruction, a load matches only DR0. The DR6 register is expected to still contain FFFF0FF5h, but the processor will update DR6 to FFFF0FF1h.
- A data breakpoint that is set on a load to uncacheable memory may be ignored due to an internal segment register access conflict. In this case the system will continue to execute instructions, bypassing the intended breakpoint. Avoiding having instructions that access segment descriptor registers, e.g., LGDT, LIDT close to the UC load, and avoiding serialized instructions before the UC load will reduce the occurrence of this erratum.

Implication: Certain debug mechanisms do not function as expected on the processor.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N38. Machine Check Architecture Error Reporting and Recovery May Not Work As Expected

Problem: When the processor detects errors it should attempt to report and/or recover from the error. In the situations described below, the processor does not report and/or recover from the error(s) as intended.

- When a transaction is deferred during the snoop phase and subsequently receives a Hard Failure response, the transaction should be removed from the bus queue so that the processor may proceed. Instead, the transaction is not properly removed from the bus queue, the bus queue is blocked, and the processor will hang.
- When a hardware prefetch results in an uncorrectable tag error in the L2 cache, IA32_MC0_STATUS.UNCOR and IA32_MC0_STATUS.PCC are set but no Machine Check Exception (MCE) is signaled. No data loss or corruption occurs because the data being prefetched has not been used. If the data location with the uncorrectable tag error is subsequently accessed, an MCE will occur. However, upon this MCE, or any other subsequent MCE, the information for that error will not be logged because IA32_MC0_STATUS.UNCOR has already been set and the MCA status registers will not contain information about the error which caused the MCE assertion but instead will contain information about the prefetch error event.
- When the reporting of errors is disabled for Machine Check Architecture (MCA) Bank 2 by setting all IA32_MC2_CTL register bits to 0, uncorrectable errors should be logged in the IA32_MC2_STATUS register but no machine-check exception should be generated. Uncorrectable loads on bank 2, which would normally be logged in the IA32_MC2_STATUS register, are not logged.
- When one half of a 64 byte instruction fetch from the L2 cache has an uncorrectable error and the other 32 byte half of the same fetch from the L2 cache has a correctable error, the processor will attempt to correct the correctable error but cannot proceed due to the uncorrectable error. When this occurs the processor will hang.
- When an L1 cache parity error occurs, the cache controller logic should write the physical address of the data memory location that produced that error into the IA32_MC1_ADDR register. In some instances of a parity error on a load operation that hits the L1 cache, however, the cache controller logic may write the physical address from a subsequent load or store operation into the IA32_MC1_ADDR register.
- The local xAPIC has an Error Status Register which records all errors which it detects. Bit 6 of this register, the Receive Illegal Vector bit, is set when the local xAPIC detects an illegal vector in a message that it received. When an illegal vector error is received on the same internal clock that the error status register is being written due to a previous error, bit 6 does not get set and illegal vector errors are not flagged.
- If an instruction fetch results in an uncorrectable error and there is also a debug breakpoint at this address, the processor will livelock and the uncorrectable error will not be logged in the machine check registers.
- The MCA Overflow bit should be set when an uncorrectable error resides within the register bank (valid bit is already set) and any subsequent errors occur. The Overflow bit being set indicates that more than one error has occurred. Because of this erratum, if any further errors occur, the MCA Overflow bit will not be updated; thereby incorrectly indicating only one error has been received.

Implication: The processor is unable to correctly report and/or recover from certain errors.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N39. Processor May Timeout Waiting for a Device to Respond after 0.67 Seconds

Problem: The PCI 2.1 target initial latency specification allows two seconds for a device to respond during initialization-time. The processor may timeout after only approximately 0.67 seconds. When the processor times out it will hang with IERR# asserted. PCI devices that take longer than 0.67 seconds to initialize may not be initialized properly.

Implication: System may hang with IERR# asserted.

Workaround: Due to the long initialization time observed on some commercially available PCI cards, it may be necessary to disable the timeout counter during the PCI initialization sequence. This can be accomplished by temporarily setting Bit 5 of the MISC_ENABLES_MSR located at address 1A0H to 1. This model specific register (MSR) is software visible but should only be set for the duration of the PCI initialization sequence. It is necessary to re-enable the timeout counter by clearing this bit after completing the PCI initialization sequence. CAUTION: The processor's Thermal Monitor feature may not function if the timeout counter is not re-enabled after completing the PCI initialization.

After the system is fully initialized, this erratum may occur either when a PCI device is hot added into the system or when a PCI device is transitioned from D3 cold. System software responsible for completing the hot add and the power state transition from D3 cold should allow for a delay of the target initial latency prior to initiating configuration accesses to the PCI device.

Status: For the steppings affected, see the *Summary Table of Changes*.

N40. Cascading of Performance Counters Does Not Work Correctly When Forced Overflow Is Enabled

Problem: The performance counters are organized into pairs. When the CASCADE bit of the Counter Configuration Control Register (CCCR) is set, a counter that overflows will continue to count in the other counter of the pair. The FORCE_OVF bit forces the counters to overflow on every non-zero increment. When the FORCE_OVF bit is set, the counter overflow bit will be set but the counter no longer cascades.

Implication: The performance counters do not cascade when the FORCE_OVF bit is set.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N41. Possible Machine Check Due to Line-Split Loads with Page-Tables in Uncacheable (UC) Space

Problem: The processor issues a speculative load which splits a 64-byte cache line. At the same time the page miss handling logic completes a page-walk for a different load. The resulting translation fills the DTLB and evicts the TLB entry to be used by the line-split load. Since the page tables are located in UC memory, this generates a load on the system bus for the Page Directory Entry (PDE). Due to an internal boundary condition, this load blocks any subsequent loads from the completing.

Implication: The timeout counter activates leading to a machine check.

Workaround: Avoid placing the page directory and the page table in uncacheable memory space.

Status: For the steppings affected, see the *Summary Table of Changes*.

N42. IA32_MC1_STATUS MSR ADDRESS VALID Bit May Be Set When No Valid Address Is Available

Problem: The processor should only log the address for L1 parity errors in the IA32_MC1_STATUS MSR if a valid address is available. If a valid address is not available, the ADDRESS VALID bit in the IA32_MC1_STATUS MSR should not be set. In instances where an L1 parity error occurs and the address is not available because the linear to physical address translation is not complete or an internal resource conflict has occurred, the ADDRESS VALID bit is incorrectly set.

Implication: The ADDRESS VALID bit is set even though the address is not valid.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N43. EMON Event Counting of x87 Loads May Not Work As Expected

Problem: If a performance counter is set to count x87 loads and floating point exceptions are unmasked, the FPU Operand Data Pointer (FDP) may become corrupted.

Implication: When this erratum occurs, the FPU Operand Data Pointer (FDP) may become corrupted.

Workaround: This erratum will not occur with floating point exceptions masked. If floating point exceptions are unmasked, then performance counting of x87 loads should be disabled.

Status: For the steppings affected, see the *Summary Table of Changes*.

N44. Software Controlled Clock Modulation Using a 12.5% or 25% Duty Cycle May Cause the Processor to Hang

Problem: Processor clock modulation may be controlled via a processor register (IA32_THERM_CONTROL). The On-Demand Clock Modulation Duty Cycle is controlled by bits 3:1. If these bits are set to a duty cycle of 12.5% or 25%, the processor may hang while attempting to execute a floating-point instruction. In this failure, the last instruction pointer (LIP) is pointing to a floating-point instruction whose instruction bytes are in UC space and which takes an exception 16 (floating point error exception). The processor stalls trying to fetch the bytes of the faulting floating-point instruction and those following it. This processor hang is caused by interactions between thermal control circuit and floating-point event handler.

Implication: The processor will go into a sleep state from which it fails to return.

Workaround: Use a duty cycle other than 12.5% or 25%.

Status: For the steppings affected, see the *Summary Table of Changes*.

N45. Speculative Page Fault May Cause Livelock

Problem: If the processor detects a page fault which is corrected before the operating system page fault handler can be called e.g., DMA activity modifies the page tables and the corrected page tables are left in a non-accessed or not dirty state, the processor may livelock. Intel has not been able to reproduce this erratum with commercial software.

Implication: Should this erratum be encountered the processor will livelock resulting in a system hang or operating system failure.

Workaround: It is possible for the BIOS to contain a workaround for this erratum.

Status: For the steppings affected, see the *Summary Table of Changes*.

N46. PAT Index MSB May Be Calculated Incorrectly

Problem: When Mode B or Mode C paging support is enabled and all of the following events occur:

- A page walk occurs that returns a large page from memory, and
- A second page walk occurs that hits an internal processor cache for a 4k page and the Page Attribute Table (PAT) upper index bit in the Page Table Entry for this page is set to 1b.

It is possible that the PAT upper index bit in the PTE for this 4k page is incorrectly ignored and assumed to be 0b. The result is that the memory type in the PAT that should have come from the corresponding PAT index [4-7] incorrectly comes from PAT index [0-3].

Implication: If an operating system has programmed the PAT in an asymmetrical fashion i.e. PAT[0-3] is different from PAT[4-7] then an incorrect memory type may be used.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N47. SQRTPD and SQRTSD May Return QNaN Indefinite Instead of Negative Zero

Problem: When DAZ mode is enabled, and a SQRTPD or SQRTSD instruction has a negative denormal operand, the instruction will return a QNaN indefinite when the specified response should be a negative zero

Implication: When this erratum occurs, the instruction will return a QNaN indefinite when a negative zero is expected.

Workaround: Ensure that negative denormals are not used as operands to the SQRTPD or SQRTSD instructions when DAZ mode is enabled. Software could enable FTZ mode to ensure that negative denormals are not generated by computation prior to execution of a SQRTPD or SQRTSD instruction.

Status: For the steppings affected, see the *Summary Table of Changes*.

N48. Bus Invalidate Line Requests that Return Unexpected Data May Result in L1 Cache Corruption

Problem: When a Bus Invalidate Line (BIL) request receives unexpected data from a deferred reply, and a store operation write combines to the same address, there is a small window where the L0 is corrupt, and loads can retire with this corrupted data. This erratum occurs in the following scenario:

- A Read-For-Ownership (RFO) transaction is issued by the processor and hits a line in shared state in the L1 cache.
- The RFO is then issued on the system bus as a 0 length Read-Invalidate (a BIL), since it doesn't need data, just ownership of the cache line.
- This transaction is deferred by the chipset.
- At some later point, the chipset sends a deferred reply for this transaction with an implicit write-back response. For this erratum to occur, no snoop of this cache line can be issued between the BIL and the deferred reply.
- The processor issues a write-combining store to the same cache line while data is returning to the processor. This store straddles an 8-byte boundary.
- Due to an internal boundary condition, a time window exists where the L1 cache contains corrupt data which could be accessed by a load.

Implication: No known commercially available chipsets trigger the failure conditions.

Workaround: The chipset could issue a BIL (snoop) to the deferred processor to eliminate the failure conditions.

Status: For the steppings affected, see the *Summary Table of Changes*.

N49. Write Combining (WC) Load May Result in Unintended Address on System Bus

Problem: When the processor performs a speculative write combining (WC) load, down the path of a mispredicted branch, and the address happens to match a valid UnCacheable (UC) address translation with the Data Translation Look-Aside Buffer, an unintended UnCacheable load operation may be sent out on the system bus

Implication: When this erratum occurs, an unintended load may be sent on system bus. Intel has only encountered this erratum during pre-silicon simulation.

Workaround: It is possible for the BIOS to contain a workaround for this erratum.

Status: For the steppings affected, see the *Summary Table of Changes*.

N50. Incorrect Data May Be Returned When Page Tables Are in Write Combining (WC) Memory Space

Problem: If page directories and/or page tables are located in Write Combining (WC) memory, speculative loads to cacheable memory may complete with incorrect data.

Implication: Cacheable loads to memory mapped using page tables located in write combining memory may return incorrect data. Intel has not been able to reproduce this erratum with commercially available software.

Workaround: Do not place page directories and/or page tables in WC memory.

Status: For the steppings affected, see the *Summary Table of Changes*.

N51. Buffer on Resistance May Exceed Specification

Problem: The datasheet specifies the resistance range for R_{ON} (Buffer On Resistance) for the AGTL+ and Asynchronous GTL+ buffers as 5 to 11 Ohms. Due to this erratum, R_{ON} may be as high as 13.11 Ohms.

Implication: The R_{ON} value affects the voltage level of the signals when the buffer is driving the signal low. A higher R_{ON} may adversely affect the system's ability to meet specifications such as V_{IL} . As the system design also affects margin to specification, designs may or may not have sufficient margin to function properly with an increased R_{ON} . System designers should evaluate whether a particular system is affected by this erratum. Designs that follow the recommendations in the *Intel® Pentium® 4 Processor and Intel® 850 Chipset Platform Design Guide* are not expected to be affected.

Workaround: No workaround is necessary for systems with margin sufficient to accept a higher R_{ON} .

Status: For the steppings affected, see the *Summary Table of Changes*.



N52. Processor Issues Inconsistent Transaction Size Attributes for Locked Operation

Problem: When the processor is in the Page Address Extension (PAE) mode and detects the need to set the Access and/or Dirty bits in the page directory or page table entries, the processor sends an 8 byte load lock onto the system bus. A subsequent 8 byte store unlock is expected, but instead a 4 byte store unlock occurs. Correct data is provided since only the lower bytes change, however external logic monitoring the data transfer may be expecting an 8-byte store unlock.

Implication: No known commercially available chipsets are affected by this erratum.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N53. Multiple Accesses to the Same S-State L2 Cache Line and ECC Error Combination May Result in Loss of Cache Coherency

Problem: When a Read for Ownership (RFO) cycle has a 64-bit address match with an outstanding read hit on a line in the L2 cache which is in the S-state AND that line contains an ECC error, the processor should recycle the RFO until the ECC error is handled. Due to this erratum, the processor does not recycle the RFO and attempts to service both the RFO and the read hit at the same time.

Implication: When this erratum occurs, cache may become incoherent.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N54. Processor May Hang When Resuming from Deep Sleep State

Problem: When resuming from the Deep Sleep state the address strobe signals (ADSTB[1:0]#) may become out of phase with respect to the system bus clock (BCLK).

Implication: When this erratum occurs, the processor will hang.

Workaround: The system BIOS should prevent the processor from going to the Deep Sleep state.

Status: For the steppings affected, see the *Summary Table of Changes*.

N55. When the Processor Is in the System Management Mode (SMM), Debug Registers May Be Fully Writeable

Problem: When in System Management Mode (SMM), the processor executes code and stores data in the SMRAM space. When the processor is in this mode and writes are made to DR6 and DR7, the processor should block writes to the reserved bit locations. Due to this erratum, the processor may not block these writes. This may result in invalid data in the reserved bit locations.

Implication: Reserved bit locations within DR6 and DR7 may become invalid.

Workaround: Software may perform a read/modify/write when writing to DR6 and DR7 to ensure that the values in the reserved bits are maintained.

Status: For the steppings affected, see the *Summary Table of Changes*.

N56. Associated Counting Logic Must Be Configured When Using Event Selection Control (ESCR) MSR

Problem: ESCR MSRs allow software to select specific events to be counted, with each ESCR usually associated with a pair of performance counters. ESCRs may also be used to qualify the detection of at-retirement events that support precise-event-based sampling (PEBS). A number of performance metrics that support PEBS require a 2nd ESCR to tag uops for the qualification of at-retirement events. (The first ESCR is required to program the at-retirement event.) Counting is enabled via counter configuration control registers (CCCR) while the event count is read from one of the associated counters. When counting logic is configured for the subset of at-retirement events that require a second ESCR to tag uops, at least one of the CCCRs in the same group of the second ESCR must be enabled.

Implication: If no CCCR/counter is enabled in a given group, the ESCR in that group that is programmed for tagging uops will have no effect. Hence a subset of performance metrics that require a second ESCR for tagging uops may result in 0 count.

Workaround: Ensure that at least one CCCR/counter in the same group as the tagging ESCR is enabled for those performance metrics that require two ESCRs and tagging uops for at-retirement counting.

Status: For the steppings affected, see the *Summary Table of Changes*.

N57. IA32_MC0_ADDR and IA32_MC0_MISC Registers Will Contain Invalid or Stale Data Following a Data, Address, or Response Parity Error

Problem: If the processor experiences a data, address, or response parity error, the ADDR_V and MISC_V bits of the IA32_MC0_STATUS register are set, but the IA32_MC0_ADDR and IA32_MC0_MISC registers are not loaded with data regarding the error.

Implication: When this erratum occurs, the IA32_MC0_ADDR and IA32_MC0_MISC registers will contain invalid or stale data.

Workaround: Ignore any information in the IA32_MC0_ADDR and IA32_MC0_MISC registers after a data, address or response parity error.

Status: For the steppings affected, see the *Summary Table of Changes*.



N58. CR2 May Be Incorrect or an Incorrect Page Fault Error Code May Be Pushed onto Stack after Execution of an LSS Instruction

Problem: Under certain timing conditions, the internal load of the selector portion of the LSS instruction may complete with potentially incorrect speculative data before the load of the offset portion of the address completes. The incorrect data is corrected before the completion of the LSS instruction but the value of CR2 and the error code pushed on the stack are reflective of the speculative state. Intel has not observed this erratum with commercially available software.

Implication: When this erratum occurs, the contents of CR2 may be off by two, or an incorrect page fault error code may be pushed onto the stack.

Workaround: It is possible for the BIOS to contain a workaround for this erratum.

Status: For the steppings affected, see the *Summary Table of Changes*.

N59. BPM[5:3]# VIL Does Not Meet Specification

Problem: The V_{IL} for BPM[5:3]# is specified as $0.9 * GTLREF [V]$. Due to this erratum the V_{IL} for these signals is $0.9 * GTLREF - .100 [V]$.

Implication: The processor requires a lower input voltage than specified to recognize a low voltage on the BPM[5:3]# signals.

Workaround: When intending to drive the BPM[5:3]# signals a low, ensure that the system provides a voltage lower than $0.9 * GTLREF - .100 [V]$.

Status: For the steppings affected, see the *Summary Table of Changes*.

N60. Processor May Hang under Certain Frequencies and 12.5% STPCLK# Duty Cycle

Problem: If a system de-asserts STPCLK# at a 12.5% duty cycle, the processor is running below 2 GHz, and the processor thermal control circuit (TCC) on-demand clock modulation is active, the processor may hang. This erratum does not occur under the automatic mode of the TCC.

Implication: When this erratum occurs, the processor will hang.

Workaround: If use of the on-demand mode of the processor's TCC is desired in conjunction with STPCLK# modulation, then assure that STPCLK# is not asserted at a 12.5% duty cycle.

Status: For the steppings affected, see the *Summary Table of Changes*.

N61. System May Hang if a Fatal Cache Error Causes Bus Write Line (BWL) Transaction to Occur to the Same Cache Line Address As an Outstanding Bus Read Line (BRL) or Bus Read-Invalidate Line (BRIL)

Problem: A processor internal cache fatal data ECC error may cause the processor to issue a BWL transaction to the same cache line address as an outstanding BRL or BRIL. As it is not typical behavior for a single processor to have a BWL and a BRL/BRIL concurrently outstanding to the same address, this may represent an unexpected scenario to system logic within the chipset.

Implication: The processor may not be able to fully execute the machine check handler in response to the fatal cache error if system logic does not ensure forward progress on the system bus under this scenario.

Workaround: System logic should ensure completion of the outstanding transactions. Note that during recovery from a fatal data ECC error, memory image coherency of the BWL with respect to BRL/BRIL transactions is not important. Forward progress is the primary requirement.

Status: For the steppings affected, see the *Summary Table of Changes*.

N62. L2 Cache May Contain Stale Data in the Exclusive State

Problem: If a cacheline (A) is in Modified (M) state in the write-combining (WC) buffers and in the Invalid (I) state in the L2 cache and its adjacent sector (B) is in the Invalid (I) state and the following scenario occurs:

1. A read to B misses in the L2 cache and allocates cacheline B and its associated second-sector prefetch into an almost full bus queue,
2. A Bus Read Line (BRL) to cacheline B completes with HIT# and fills data in Shared (S) state,
3. The bus queue full condition causes the prefetch to cacheline A to be cancelled, cacheline A will remain M in the WC buffers and I in the L2 while cacheline B will be in the S state.

Then, if the further conditions occur:

1. Cacheline A is evicted from the WC Buffers to the bus queue which is still almost full,
2. A hardware prefetch Read for Ownership (RFO) to cacheline B, hits the S state in the L2 and observes cacheline A in the I state, allocates both cachelines,
3. An RFO to cacheline A completes before the WC Buffers write modified data back, filling the L2 with stale data,
4. The writeback from the WC Buffers completes leaving stale data, for cacheline A, in the Exclusive (E) state in the L2 cache.

Implication: Stale data may be consumed leading to unpredictable program execution. Intel has not been able to reproduce this erratum with commercial software.

Workaround: It is possible for BIOS to contain a workaround for this erratum.

Status: For the steppings affected, see the *Summary Table of Changes*.



N63. Re-Mapping The APIC Base Address to a Value Less Than or Equal to 0xDC001000 May Cause IO and Special Cycle Failure

Problem: Remapping the APIC base address from its default can cause conflicts with either I/O or special cycle bus transactions.

Implication: Either I/O or special cycle bus transactions can be redirected to the APIC, instead of appearing on the front-side bus.

Workaround: Use any APIC base addresses above 0xDC001000 as the relocation address.

Status: For the steppings affected, see the *Summary Table of Changes*.

N64. Erroneous BIST Result Found in EAX Register after Reset

Problem: The processor may show an erroneous BIST (built-in self test) result in the EAX register bit 0 after coming out of reset.

Implication: When this erratum occurs, an erroneous BIST failure will be reported in the EAX register bit 0, however this failure can be ignored since it is not accurate.

Workaround: It is possible for BIOS to workaround this issue by masking off bit 0 in the EAX register where BIST results are written.

Status: For the steppings affected, see the *Summary Table of Changes*.

N65. Processor Does Not Flag #GP on Non-Zero Write to Certain MSRs

Problem: When a non-zero write occurs to the upper 32 bits of IA32_CR_SYSENTER_EIP or IA32_CR_SYSENTER_ESP, the processor should indicate a general protection fault by flagging #GP. Due to this erratum, the processor does not flag #GP.

Implication: The processor unexpectedly does not flag #GP on a non-zero write to the upper 32 bits of IA32_CR_SYSENTER_EIP or IA32_CR_SYSENTER_ESP. No known commercially available operating system has been identified to be affected by this erratum.

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N66. Simultaneous Assertion of A20M# and INIT# May Result in Incorrect Data Fetch

Problem: If A20M# and INIT# are simultaneously asserted by software, followed by a data access to the 0xFFFFFXXX memory region, with A20M# still asserted, incorrect data will be accessed. With A20M# asserted, an access to 0xFFFFFXXX should result in a load from physical address 0xFFEFFXXX. However, in the case of A20M# and INIT# being asserted together, the data load will actually be from the physical address 0xFFFFFXXX. Code accesses are not affected by this erratum.

Implication: Processor may fetch incorrect data, resulting in BIOS failure.

Workaround: Deasserting and reasserting A20M# prior to the data access will workaround this erratum.

Status: For the steppings affected, see the *Summary Table of Changes*.

N67. CPUID Instruction Returns Incorrect Number of ITLB Entries

Problem: When CPUID instruction is executed with EAX = 2 on a processor without Hyper-Threading Technology or with Hyper-Threading Technology disabled via power on configuration, it should return a value of 51h in EAX[15:8] to indicate that the Instruction Translation Lookaside Buffer (ITLB) has 128 entries. On a processor with Hyper-Threading Technology enabled, the processor should return 50h (64 entries). Due to this erratum, the CPUID instruction always returns 50h (64 entries).

Implication: Software may incorrectly report the number of ITLB entries. Operation of the processor is not affected

Workaround: None identified.

Status: For the steppings affected, see the *Summary Table of Changes*.

N68. A Write to APIC Registers Sometimes May Appear to Have Not Occurred

Problem: In respect to the retirement of instructions, stores to the uncacheable memory-based APIC register space are handled in a non-synchronized way. For example if an instruction that masks the interrupt flag, e.g. CLI, is executed soon after an uncacheable write to the Task Priority Register (TPR) that lowers the APIC priority, the interrupt masking operation may take effect before the actual priority has been lowered. This may cause interrupts whose priority is lower than the initial TPR, but higher than the final TPR, to not be serviced until the interrupt flag is finally cleared, i.e. by STI instruction. Interrupts will remain pending and are not lost.

Implication: In this example the processor may allow interrupts to be accepted but may delay their service.

Workaround: This non-synchronization can be avoided by issuing an APIC register read after the APIC register write. This will force the store to the APIC register before any subsequent instructions are executed. No commercial operating system is known to be impacted by this erratum.

Status: For the steppings affected, see the *Summary Table of Changes*.



N69. Missing Stop-Clock Acknowledge from the Processor

Problem: If a STPCLK_ACK bus cycle is deferred by an agent external to the processor for a period of time long enough for the chipset to deassert and then reassert STPCLK#, a Hyper-Threading Technology enabled processor may fail to detect the de-assertion/reassertion and hence will not generate a STPCLK_ACK in response to the second STPCLK# assertion, causing the system to hang.

Implication: This condition will result in a system hang. Intel has not observed this erratum with any commercially available software, system, nor components.

Workaround: It is possible for the BIOS to contain a workaround for this erratum

Status: For the steppings affected, see the *Summary Table of Changes*.

N70. Store to Load Data Forwarding May Result in Switched Data Bytes

Problem: If in a short window after an instruction that updates a segment register has executed, but has not yet retired, there is a load occurring to an address, that matches a recent previous store operation, but the data size is smaller than the size of the store, the resulting data forwarded from the store to the load may have some of the lower bytes switched.

Implication: If this erratum occurs, the processor may execute with incorrect data.

Workaround: It is possible for the BIOS to contain a workaround for this erratum.

Status: For the steppings affected, see the Summary of Changes at the beginning of this section.

N71. Parity Error in the L1 Cache May Cause the Processor to Hang

Problem: If a locked operation accesses a line in the L1 cache that has a parity error, it is possible that the processor may hang while trying to evict the line.

Implication: If this erratum occurs, it may result in a system hang. Intel has not observed this erratum with any commercially available software.

Workaround: None.

Status: For the steppings affected, see the *Summary Table of Changes*.

N72. The TCK Input in the Test Access Port (TAP) is Sensitive to Low Clock Edge Rates and Prone to Noise Coupling Onto TCK's Rising or Falling Edges

Problem: TCK is susceptible to double clocking when low amplitude noise occurs on TCK edge, while it is crossing the receiver's transition region. TAP failures tend to increase with increases in background system noise.

Implication: This only impacts JTAG/TAP accesses to the processor. Other bus accesses are not affected.

Workaround: To minimize the effects of this issue, reduce noise on the TCK-net at the processor relative to ground, and position TCK relative to BCLK to minimize the TAP error rate. Decreasing rise times to under 800ps reduces the failure rate but does not stop all failures.

Status: For the steppings affected, see *the Summary of Changes* at the beginning of this section.

N73. Disabling a Local APIC Disables Both Logical Processor APICs on a Hyper-Threading Technology Enabled Processor

Problem: Disabling a local APIC on one logical processor of a Hyper-Threading Technology enabled processor by clearing bit 11 of the IA32_APIC_BASE MSR will effectively disable the local APIC on the other logical processor.

Implication: Disabling a local APIC on one logical processor prevents the other logical processor from sending or receiving interrupts. Multiprocessor Specification compliant BIOSs and multiprocessor operating systems typically leave all local APICs enabled preventing any end-user visible impact from this erratum.

Workaround: Do not disable the local APICs in a Hyper-Threading Technology enabled processor.

Status: For the steppings affected, see the Summary of Changes at the beginning of this section.

N74. A Circuit Marginality in the 800 MHz Front Side Bus Power Save Circuitry May Cause a System and/or Application Hang or May Result in Incorrect Data

Problem: On a small percentage of processors, a race condition exists in the power save logic of the internal clock circuitry controlling the movement of data to the data bus pins. This may result in system or application hang or may cause incorrect data.

Implication: When this erratum occurs, system and/or application may hang or result in incorrect data.

Workaround: It is possible for the BIOS to contain a workaround for this erratum. During the BIOS POST, prior to memory initialization the BIOS must load the microcode update.

Status: For the steppings affected,, see the *Summary Tables of Changes*.

N75. Using STPCLK and Executing Code from Very Slow Memory Could Lead to a System Hang

Problem: The system may hang when the following conditions are met:

- 1) Periodic STPCLK mechanism is enabled via the chipset
- 2) Hyper-Threading Technology is enabled
- 3) One logical processor is waiting for an event (i.e., hardware interrupt)
- 4) The other logical processor executes code from very slow memory such that every code fetch is deferred long enough for the STPCLK to be re-asserted.

Implication: If this erratum occurs, the processor will go into and out of the sleep state without making forward progress, since the logical processor will not be able to service any pending event. This erratum has not been observed in any commercial platform running commercial software.

Workaround: None

Status: For the steppings affected, see the *Summary Tables of Changes*.

N76. Changes to CR3 Register do not Fence Pending Instruction Page Walks

Problem: When software writes to the CR3 register, it is expected that all previous/outstanding code, data accesses and page walks be completed using the previous value in CR3 register. Due to this erratum, it is possible that a pending instruction page walk is still in progress, resulting in an access (to the PDE portion of the page table) that may be directed to an incorrect memory address.

Implication: The processor will not consume the results of the access to the PDE so the return of incorrect data is benign. However, the system may hang if the access to the PDE does not complete with data (e.g., infinite number of retries).

Workaround: It is possible for the BIOS to contain a workaround for this erratum.

Status: For the steppings affected, see the *Summary Tables of Changes*.

N77. The State of the Resume Flag (RF Flag) in a Task-State Segment (TSS) May be Incorrect

Problem: After executing a JMP instruction to the next (or other) task through a hardware task switch, it is possible for the state of the RF flag (in the EFLAGS register image) to be incorrect.

Implication: The RF flag is normally used for code breakpoint management during debug of an application. It is not typically used during normal program execution. Code breakpoints or single step debug behavior in the presence of hardware task switches, therefore, may be unpredictable as a result of this erratum. This erratum has not been observed in commercially available software.

Workaround: None

Status: For the steppings affected, see the *Summary Tables of Changes*.

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Specification Changes

The Specification Changes listed in this section apply to the following documents:

- *Intel® Pentium® 4 Processor in the 423-pin Package, Intel® Pentium® 4 Processor in the 478-pin Package Datasheet*
- *Intel® Pentium® 4 Processor in the 478-pin Package Datasheet*
- *Intel® Pentium® 4 Processor with 512-KB L2 Cache on 0.13 Micron Process Datasheet*

All Specification Changes will be incorporated into a future version of the appropriate Pentium 4 processor documentation.

N1. PWRGOOD Specification Changes

The following changes will be made to the *Intel® Pentium® 4 Processor in the 423-pin Package, Intel® Pentium® 4 Processor in the 478-pin Package Datasheet*, and *Intel® Pentium® 4 Processor with 512-KB L2 Cache on 0.13 Micron Process Datasheet* (Note that table and figure numbers refer to the *Intel® Pentium® 4 Processor with 512-KB L2 Cache on 0.13 Micron Process Datasheet*. The corresponding tables and figures will be updated in the other documents):

In the *Systems Bus Pin Groups* table (Table 4) PWRGOOD will be moved from the Asynchronous GTL+ Input group to the Power/Other group.

In the Chapter 2 section titled *Asynchronous GTL+ Signals* PWRGOOD will be removed from the list of signals.

In Chapter 5, the Signal Buffer Type of PWRGOOD will change from Asynch GTL+ to Power/Other (in both Table 34 and 35).

Table 12 will be renamed to *PWRGOOD and TAP Signal Group DC Specifications*.

TAP will be removed from the descriptions of the VHYS, VT+, and VT- parameters in Table 12.

Table 14 will be renamed to *Miscellaneous Signals AC Specifications*.

Timing T35 will have “except PWRGOOD” removed from the parameter description.

Note 2 to Table 14 will have the following sentence added: “PWRGOOD is referenced to the BCLK0 rising edge at 0.5 * VCC.”

Table 25 will be renamed to *Ringback Specifications for PWRGOOD and TAP Signal Groups*.

The Signal Groups rows of Table 25 will change to read: *TAP and PWRGOOD*.

Figure 23 will be renamed to *Low-to-High System Bus Receiver Ringback Tolerance for PWRGOOD and TAP Buffers*.

Figure 24 will be renamed to *High-to-Low System Bus Receiver Ringback Tolerance for PWRGOOD and TAP Buffers*.

Table 29 will be renamed to *Asynchronous GTL+, PWRGOOD, and TAP Signal Groups Overshoot/Undershoot Tolerance*.

Specification Clarifications

The Specification Clarifications listed in this section apply to the following documents:

- *Intel® Pentium® 4 Processor in the 423-pin Package, Intel® Pentium® 4 Processor in the 478-pin Package Datasheet*
- *Intel® Pentium® 4 Processor in the 478-pin Package Datasheet*
- *Intel® Pentium® 4 Processor with 512-KB L2 Cache on 0.13 Micron Process Datasheet*

All Specification Clarifications will be incorporated into a future version of the appropriate Pentium 4 processor documentation.

N1. Clarifying DBI# Definition for All Processors with Intel® NetBurst™ Microarchitecture

The definition of DBI# signals will be clarified for Pentium4 processors with Intel® NetBurst™ microarchitecture. The new definition will state:

DBI[3:0]# are source synchronous and indicate the polarity of the D[63:0]# signals. The DBI[3:0]# signals are activated when the data on the data bus is inverted. If more than half of the data bits, within a 16-bit group, would have been asserted electrically low, the bus agent may invert the data bus signals for that particular sub-phase for that 16-bit group.

N2. Thermal Specification Clarification

In the “Thermal Specifications and Design Considerations” section of the *Intel® Pentium® 4 Processor with 512KB L2 Cache on 0.13 Micron Process Electrical, Mechanical, and Thermal Specifications (EMTS)* and *Intel® Pentium® 4 Processor with 512KB L2 Cache on 0.13 Micron Process datasheet*, the thermal specification verbiage has now changed to emphasize the long-term reliability performance degradation if the thermal solutions are under-designed. In order to clarify the purpose of the thermal monitor feature, the description in that section was modified. This change will be incorporated in the next revision of the *Intel® Pentium® 4 Processor with 512KB L2 Cache on 0.13 Micron Process Electrical, Mechanical, and Thermal Specifications (EMTS)* and *Intel® Pentium® 4 Processor with 512KB L2 Cache on 0.13 Micron Process datasheet*.

Intel® Pentium® 4 Processor with 512KB L2 Cache on 0.13 Micron Process datasheet thermal section (Chapter 5):

5 Thermal Specifications and Design Considerations

5.1 Processor Thermal Specifications

The Intel® Pentium® 4 Processor with 512KB L2 Cache on 0.13 Micron Processor requires a thermal solution to maintain temperatures within the operating limits as set forth in Section 5.1.1. Any attempt

to operate the processor outside these operating limits may result in permanent damage to the processor and potentially other components within the system. As processor technology changes, thermal management becomes increasingly crucial when building computer systems. Maintaining the proper thermal environment is key to reliable, long-term system operation.

A complete thermal solution includes both component and system level thermal management features. Component level thermal solutions can include active or passive heatsinks attached to the processor Integrated Heat Spreader (IHS). Typical system level thermal solutions may consist of system fans combined with ducting and venting.

For more information on designing a component level thermal solution, refer to Intel® Pentium® 4 Processor with 512KB L2 Cache on 0.13 Micron Process thermal design guide.

5.1.1 Thermal Specifications

To allow for the optimal operation and long-term reliability of Intel processor-based systems, the system/processor thermal solution should be designed such that the processor remains within the minimum and maximum case temperature (TC) specifications when operating at or below the Thermal Design Power (TDP) value listed per frequency in Table 5-1. Thermal solutions not designed to provide this level of thermal capability may affect the long-term reliability of the processor and system. For more details on thermal solution design, please refer to the appropriate processor thermal design guidelines.

The case temperature is defined at the geometric top center of the processor IHS. Analysis indicates that real applications are unlikely to cause the processor to consume maximum power dissipation for sustained periods of time. Intel recommends that complete thermal solution designs target the Thermal Design Power (TDP) indicated in Table 5-1 instead of the maximum processor power consumption. The Thermal Monitor feature is intended to help protect the processor in the unlikely event that an application exceeds the TDP recommendation for a sustained period of time. For more details on the usage of this feature, refer to Section 6-3. To ensure maximum flexibility for future requirements, systems should be designed to the Flexible Motherboard (FMB) guidelines, even if a processor with a lower thermal dissipation is currently planned. In all cases, the Thermal Monitor feature must be enabled for the processor to remain within specification.

5.1.2.1 Processor Case Temperature Measurement

The maximum and minimum case temperature (TC) for the Intel® Pentium® 4 Processor with 512KB L2 Cache on 0.13 Micron Processor is specified in Table 5-1. This temperature specification is meant to help ensure proper operation of the processor. Figure 5-2 illustrates where Intel recommends TC thermal measurements should be made.

6.3 Thermal Monitor

The Thermal Monitor feature helps control the processor temperature by activating the Thermal Control Circuit (TCC) when the processor silicon reaches its maximum operating temperature. The TCC reduces processor power consumption by modulating (starting and stopping) the internal processor core clocks. The Thermal Monitor feature must be enabled for the processor to be operating within specifications. The temperature at which Thermal Monitor activates the thermal control circuit is not user configurable and is not software visible. Bus traffic is snooped in the normal manner, and interrupt requests are latched (and serviced during the time that the clocks are on) while the TCC is active.



When the Thermal Monitor feature is enabled, and a high temperature situation exists (i.e. TCC is active), the clocks will be modulated by alternately turning the clocks off and on at a duty cycle specific to the processor (typically 30-50%). Clocks often will not be off for more than 3.0 microseconds when the TCC is active. Cycle times are processor speed dependent and will decrease as processor core frequencies increase. A small amount of hysteresis has been included to prevent rapid active/inactive transitions of the TCC when the processor temperature is near its maximum operating temperature. Once the temperature has dropped below the maximum operating temperature, and the hysteresis timer has expired, the TCC goes inactive and clock modulation ceases.

With a properly designed and characterized thermal solution, it is anticipated that the TCC would only be activated for very short periods of time when running the most power intensive applications. The processor performance impact due to these brief periods of TCC activation is expected to be so minor that it would be immeasurable. An under-designed thermal solution that is not able to prevent excessive activation of the TCC in the anticipated ambient environment may cause a noticeable performance loss, and in some cases may result in a TC that exceeds the specified maximum temperature and may affect the long-term reliability of the processor. In addition, a thermal solution that is significantly under-designed may not be capable of cooling the processor even when the TCC is active continuously. Refer to the *Intel® Pentium® 4 Processor with 512KB L2 Cache on 0.13 Micron Process Thermal Design Guide* for information on designing a thermal solution.

The duty cycle for the TCC, when activated by the Thermal Monitor, is factory configured and cannot be modified. The Thermal Monitor does not require any additional hardware, software drivers, or interrupt handling routines.

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Documentation Changes

The Documentation Changes listed in this section apply to the following documents:

- *Intel® Pentium® 4 Processor in the 423-pin Package, Intel® Pentium® 4 Processor in the 478-pin Package Datasheet*
- *Intel® Pentium® 4 Processor in the 478-pin Package Datasheet*
- *Intel® Pentium® 4 Processor with 512-KB L2 Cache on 0.13 Micron Process Datasheet*

All Documentation Changes will be incorporated into a future version of the appropriate Pentium 4 processor documentation.

Note: Documentation changes for IA-32 Intel® Architecture Software Developer's Manual volumes 1, 2, and 3 will be posted in a separate document, *IA-32 Intel® Architecture Software Developer's Manual Documentation Changes*. Please follow the link below to become familiar with this file.

<http://developer.intel.com/design/pentium4/specupdt/252046.htm>

There are no documentation changes in this Specification Update revision.